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Electric Locomotive Haulage

in and about Mines

Mining Engineering

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ELECTRIC LOCOMOTIVE HAULAGE IN AND ABOUT MINES

BY

LEONARD VICTOR NEWTON

THESIS

FOR

DEGREE OF BACHELOR OF SCIENCE

IN

MINING ENGINEERING

COLLEGE OF ENGINEERING

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THE ELECTRIC MINE LOCOMOTIVE.

Part I.

History and Development of the Mine Locomotive.

The potential influence exerted by the electric mine locomotive on coal and ore production throughout the world, is realized only when a study is made of the production of the coal and ore of today with that which existed when mule haulage alone controlled and limited the output of the mines. It is probable that this is one of the main reasons why electric mine locomotives have come into such universal usage since the year of 1887.

The Lykens Valley Coal Co. of Pennsylvania was the first company to adopt the electric locomotive for main haulage use, and the rugged and durable character of the machine is well shown by the fact that the machine is still used about the mines. It consisted of a small electric motor mounted centrally on a very light running frame, the wheel base being very short. The transmission was of a cog and chain type; a small cog mounted on the armature shaft being connected to a larger cog by means of a chain, said larger cog being mounted on one of the axles. The total weight of the locomotive was only fifteen hundred pounds, and in order to obtain a sufficiently large draw-bar pull to haul a long train of cars, it was necessary to weight the locomotive with pig iron, the weight necessary being about seven thousand pounds. With this ballast, sufficient track resistivity was obtained to have a trip consisting of eight or nine two-ton cars of coal and a car of

shale or rock.

It is difficult to say what company was the next one to install the electric mine locomotive in their mine, but it is known definitely that shortly after the Lykens Coal Co. had completed their electric installation, the Crozer Coal and Coke Co. of Elk Horn, West Virginia purchased a Westinghouse locomotive for haulage purposes in their mine. By refering to Plate 1, which is a photograph of the first Westinghouse machine, the reader can readily see that the locomotive was very massive and clumsy. Its weight was twenty tons, and it was equipped with two motors. A very special point of construction worthy of notice is that the machine is equipped with side rods to transmit the torque of the motors to the center wheels, the motors being geared to the axles outside of the frame. Another purpose of the side rods was to equalize the load between the two motors when there might be a tendency to slip one pair of wheels due to track conditions.

From 1887 to 1888 few machines were manufactured, but in 1889 the Jeffrey Co. of Columbus Ohio, and the General Electric Co. of Schenectady New York, both put out very good locomotives. The Jeffrey machine was installed in the mine of the Upson Coal Co. of Shawnee Ohio, and it is still in successful operation. From Plates 2 and 3 one can see that the locomotive possesses many of the characteristics of the Lykens Coal Co's. machine, inasmuch as it has a very short wheel base, light weight, and is of the single motor type. Plate 3 is a photograph of the locomotive as it appears today.

In 1891, the Hunt Co. of New York built its first locomotive for the Brock Coal Co., of Brockwayville, Pennsylvania.

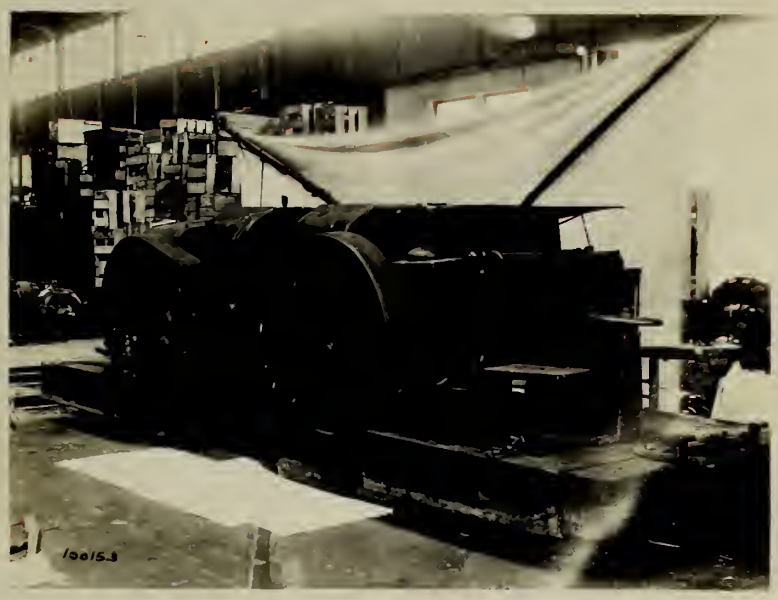


PLATE 1.

PLATE 2.

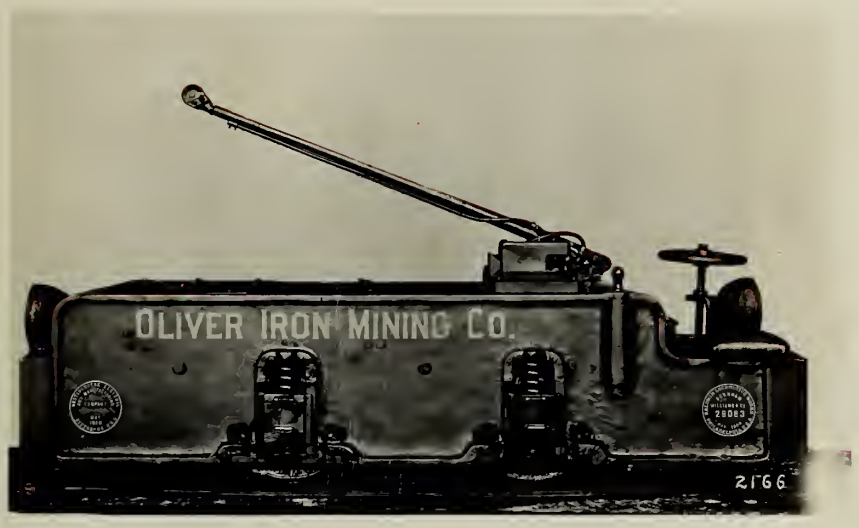
PLATE 3.

This machine was equipped with an eighteen horse power motor, series wound. The current was supplied through a trolley, and one of the rails was utilized for a return circuit.

Plate 4 is an illustration of one of the earlier locomotives, the name of the manufactuer being unknown. It differs essentialy from the others in that the wheels are connected together with connecting rods, similar to the locomotive built by the Wes tinghouse Co. for the use in the Crozer Coal and Coke Co's. mine in West Virginia. Special points of interest are the housing, the large frame buffers, and the trolley pole.

Plate 5 is an illustration of a Westinghouse Electric Co. machine, built for service in the Oliver Iron Mining Co's. mine. It is typical of the standard locomotive construction used in the mines a few years ago. The frame was made of heavy iron castings which broke very readily in collisions. Particularly in the lighter machines where the relative proportions of the weight of the electrical and mechanical equipment was high, and it was necessary to economize in the weight of the frame in order to prevent excessive weight of the locomotive. This particular type of locomotive was equipped with two motors taking 220 volts, and at full load capable of hauling the trip 6 miles per hour. The draw-bar pull was 1260 lbs. and at starting 2000 lbs. At first they were designed to weigh 8000 lbs. but on account of not being able to build the frames strong enough to withstand rough mine usage, it was necessary to increase the total weight of the locomotive to 9500 lbs. In case of collision, the frames of this type of locomotive always broke over the pedestals as this, as may be readily perceived, is the weakest point in the frame.

PLATE 4.



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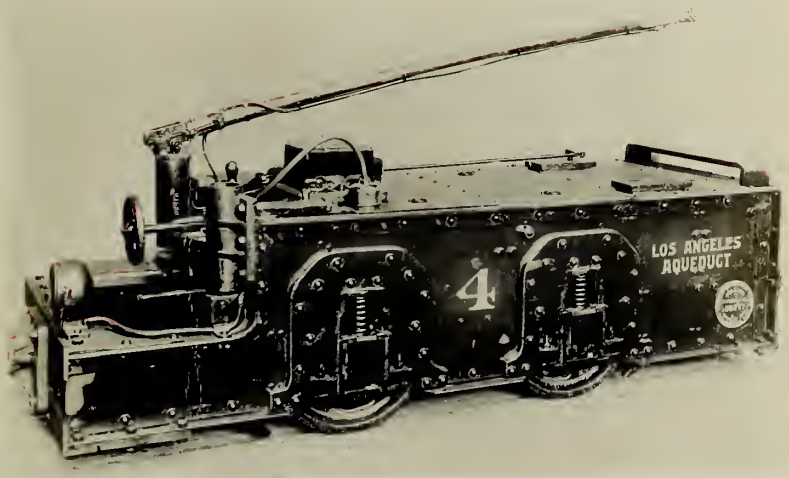


PLATE 6.

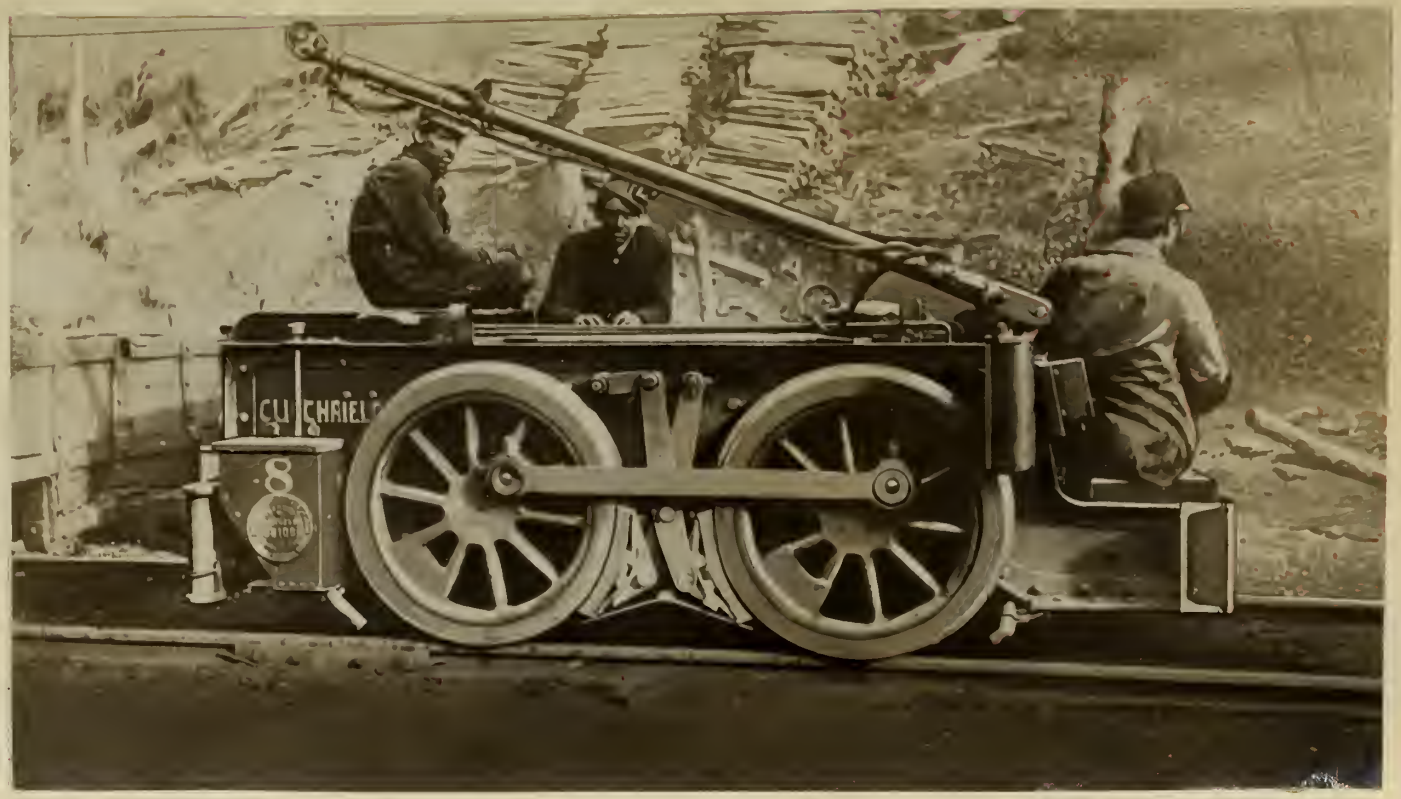


PLATE 7.

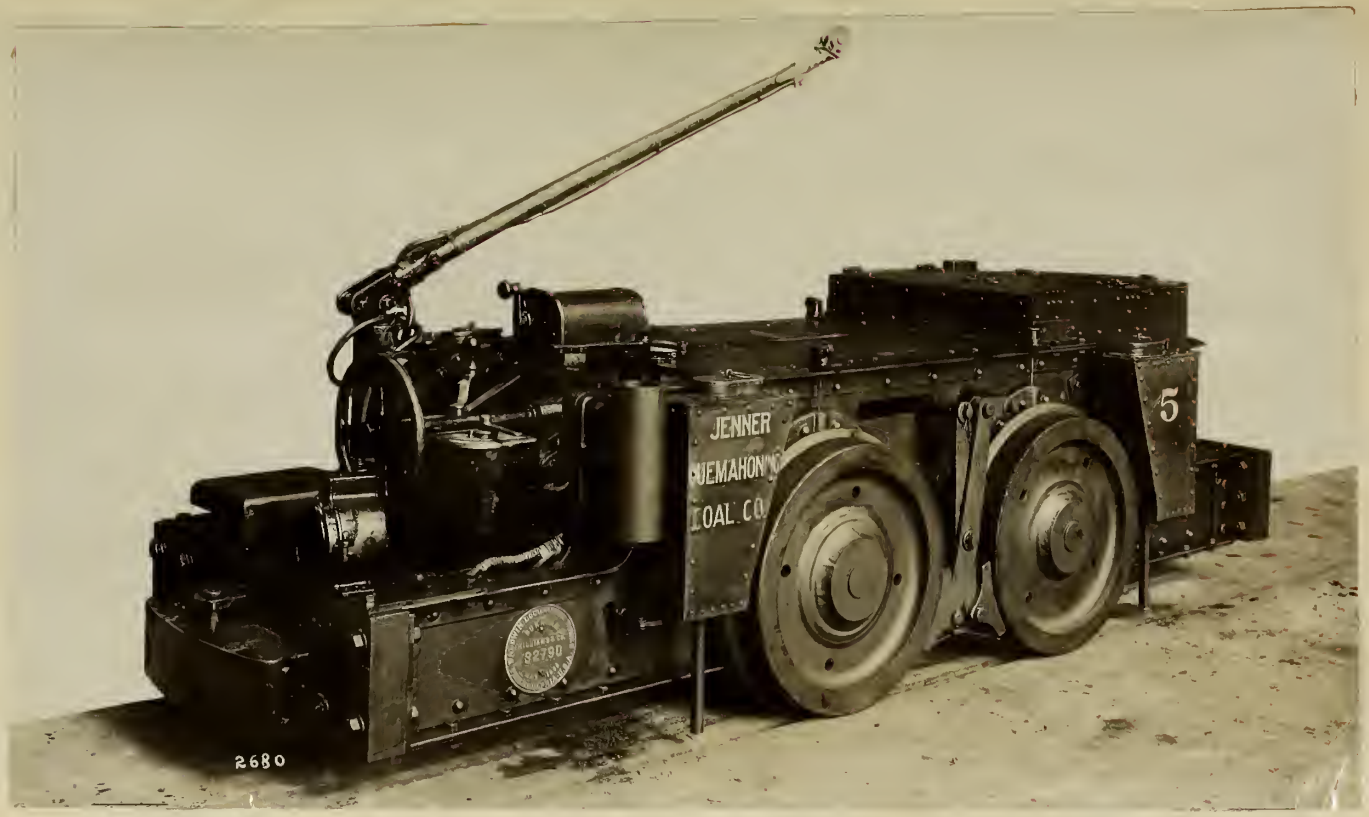


PLATE 8.

A locomotive built by the Westinghouse Electric Co. for service on the Los Angeles aqueduct is illustrated in Plate 6. It was built in the latter part of 1906, and shows very clearly the next development in frame construction, namely the use of plates and angles instead of heavy castings, cast steel pedestals however being used. This type of construction made a much stiffer frame for the same amount of material involved, and enabled the manufacturer to build the 4-ton locomotive to the estimated 8000 lbs. instead of having to weight it to 9500 lbs.

Plates 7 and 8 illustrate locomotives built by the Baldwin Westinghouse Co. in 1908, for foreign service. These photographs do not show as radical changes as do Plates 9,10, 11, and 12, these latter plates representing locomotives just recently built. The development of frame construction is very well shown in all of these photographs, heavy steel frames being now used. Plate 9 is worthy of special attention in that it represents an open frame Baldwin Westinghouse. The frame is made of cast steel and is of tee-bar construction similar to the construction of steam locomotive frames. All parts are now made accessible through the openings in the frame, and the pedestal construction with the yoke over the bar under the journal springs gives a very stiff construction, which eliminates the weakness previously existing in the cast iron frames where it was necessary to leave a space underneath the top of the castings and over the journal for the journal springs.

Plates 10 and 11 represent a twelve-ton, two-motor type electric locomotive built by the Goodman Manufacturing Co. of Chicago. As may be readily seen the frame is entirely different

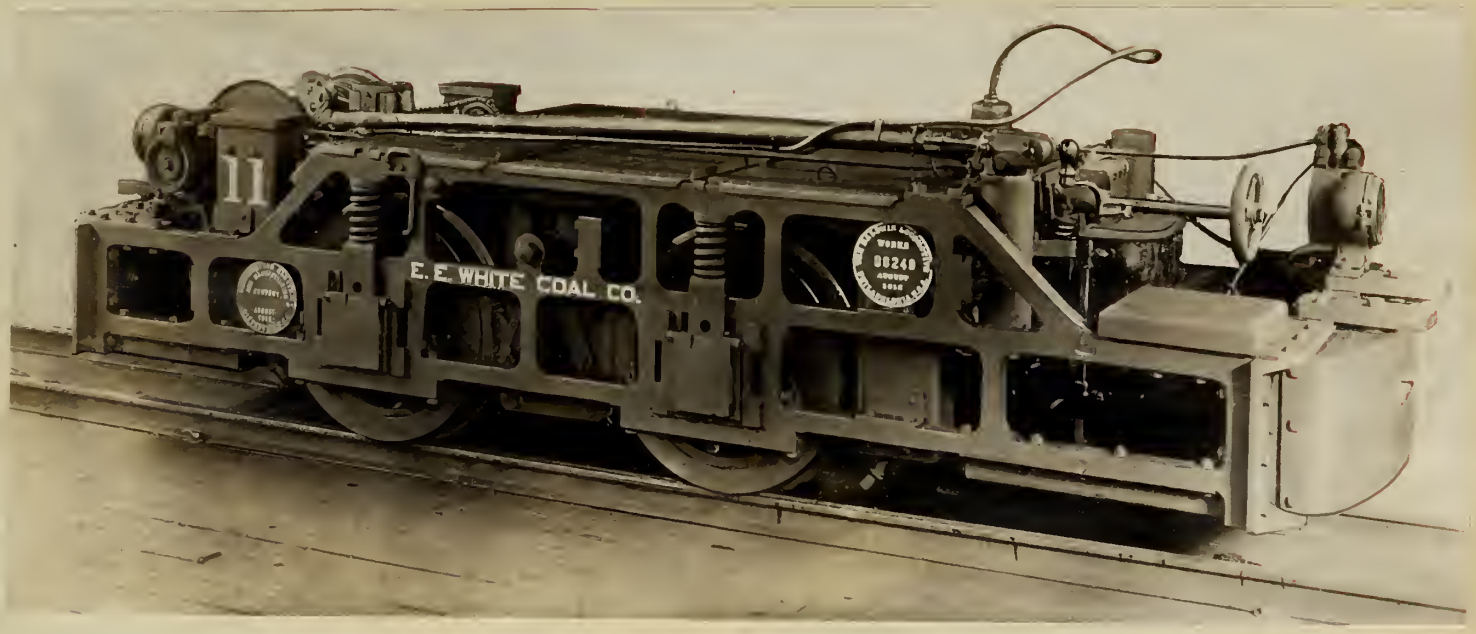


PLATE 9.

PLATE 10.

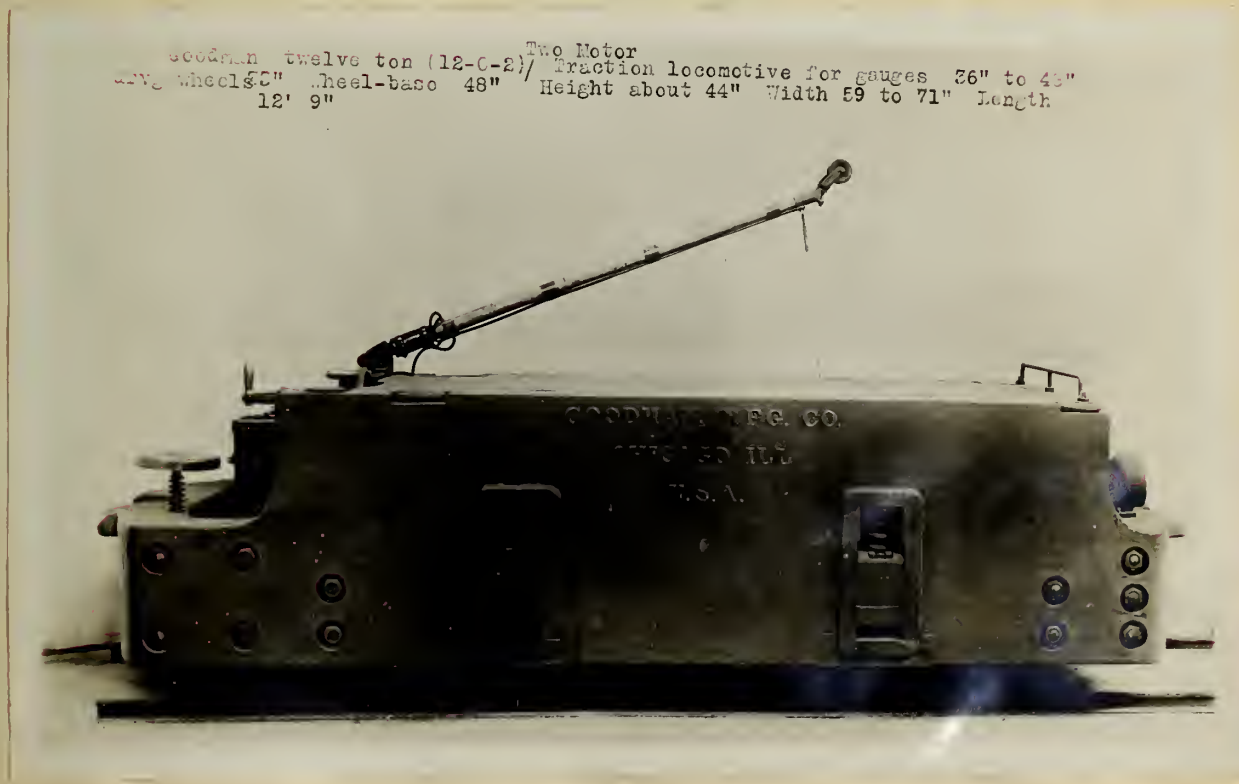


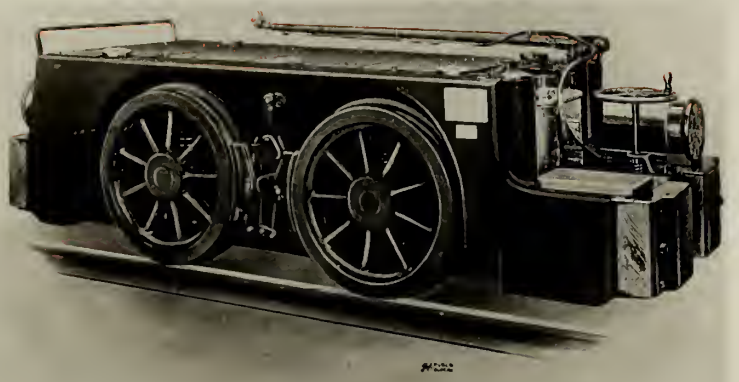
PLATE 11.

from that made by the Baldwin-Westinghouse Co.; the Goodman frame being heavy cast iron- weakness over the journal boxes being eliminated by ribbing and making the parts very heavy.

Plate 12 is a photograph of the Jeffrey armor-plate type of locomotive, and in construction differs very little from the Goodman Co's. machine illustrated in Plates 10 and 11. A further discussion of the relative merits of various frames will be taken up under the subject of General Construction of electric locomotives.

To appreciate the tremendous strides that have been made in the development of the electric locomotive, one needs only to compare Plates 1,2,3,4,5,6,7 and 8 with Plates 9,10,11 and 12, the former set of plates representing and showing the growth and development of the locomotive since its advent into this country, and the latter set representing the highest type of electric locomotive construction of today.

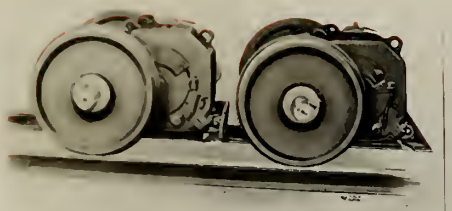
PLATE 12.



EIGHT-TON INSIDE FRAME LOCOMOTIVE

EIGHT-TON OUTSIDE FRAME LOCOMOTIVE

PLATE 12A.



MOTORS MOUNTED "TANDEM"

MOTORS MOUNTED "CENTRAL"

MOTORS "END" MOUNTED

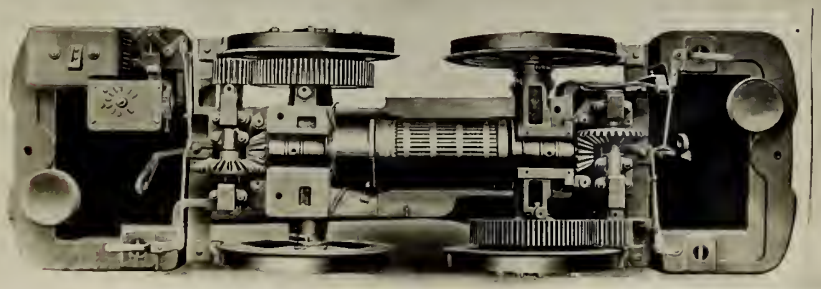


PLATE 12B.

Part II.

The General Construction of Electric Mine Locomotives

The discussion of the general construction of electric mine locomotives will be taken up under two heads,namely:- the construction of trolley locomotives and of storage battery locomotives.

The two-motor type of locomotive has come to be generally recognized as the standard type for mine haulage work,all manufacturers having adopted this type as standard with the exception of the Goodman Mfg. Co.of Chicago,which company still retains the single motor type in stock. There are two general forms of the two-motor type of locomotive,namely:- one in which the side frames are placed inside of the wheels (see Plate I2 A),and the other in which the side frames are placed outside of the wheels. For a given track guage ,the outside frame type allows the maximum space between the wheels for the motors and other parts of the equiptment,and also renders the journal boxes very accessible and makes somewhat more space at the operating end of the machine for the motorman. This type has objections however,inasmuch as it is wider than the locomotive built with the inside frame,in which the width between the wheels is very restricted,but there is a minimum over-all width giving a construction that is absolutely necessary where the props of the entry are set close to the track.

Regarding the position of the motor: the single motor as manufactured by the Goodman Co.is placed between the axles

the armature of the motor being parallel to the long dimension of the frame. At either end of the armature is a bevel gear, that meshes into another bevel gear,and is mounted on a small shaft the end of which carries a small pinion,that meshes into a cog on the axle of the machine. With this form of motor mounting ,it is claimed that the machine is given uniformity and symetry in driving,and besides it has the simplicity of construct -ion due ti its single motor design.

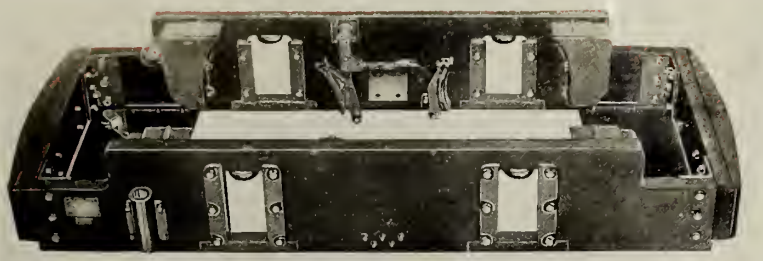
The standard method of mounting two motors on the locomotive bed are "central" mounting,and "tandem" mounting. In the former type both of the motors are placed between the axles; in the latter,one motor is placed between the forward axle and the front end of the frame,and the other between the two axles. The tandem arrangement permits of a short wheel base and is applicable to light and medium weight locomotives,where the track over which the machine is to be operated is likely to have curves of small radius. On the larger locomotives,the motors are mounted centrally because of the fact that a long wheel base is permissible,curves of very short radius being rarely found in the main passage ways of large mines. There is a third type of two-motor mounting where the motors are mounted at each end of the locomotive,between the end frame and the axle. This is scarcely ever used unless a very short wheel base is necessary,and then "teetering" or rocking is likely to occur.

The frames as made by the various manufactured are generally built of structural steel for the smaller sizes up to and including the six ton locomotives, Above this,the side frames are made of cast iron and the end frame of steel.The

steel side frames are cut from a single piece of rolled plate, and reinforced with heavy steel angles. Steel guide plates for the journal boxes are securely riveted to the frame plates, and sand boxes, trolley sockets and motor lugs are fastened on to the frame with heavy bolts.

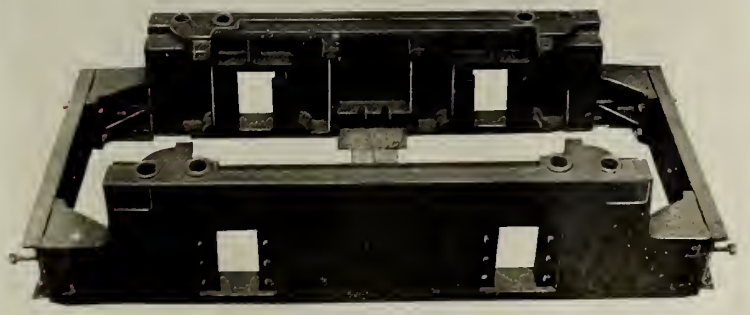
In the locomotives above six tons, great weight is necessary in order to obtain the requesite draw-bar pull. Therefore cast iron side frames and steel end frames are used. The cast iron frames are heavily ribbed in order to secure the maximum rigidity and strength. The sand boxes, motor lugs and trolley sockets are cast integral with the frame. The whole is accurately machined and bolted to secure good joints and perfect alignment. Plate 13 is an illustration of the rolled steel frame, the structural steel frame and the cast iron frame with channel ends. It will be noted that these types of frames are solid and that the motors, journal boxes and other parts of the equipment are quite inaccessible.

The Baldwin Westinghouse Co. has recently perfected an open frame, built similar to the frame of a steam locomotive (see Plate 14) and have used cast steel for the material. This makes a practically unbreakable frame, and furthermore makes all parts of the machine more accessible through the openings in the frame. To eliminate the weakness of the bar under the journal springs, a pedestal construction has been resorted to with a yoke under the bar. This gives stiffness and eliminates this point of weakness which formerly existed in cast iron frames, where it was necessary to have a space underneath the top of the casting and over the journal for the journal springs. A further advantage of



ROLLED STEEL FRAME

STRUCTURAL STEEL FRAME



CAST FRAME WITH CHANNEL ENDS

PLATE 13.

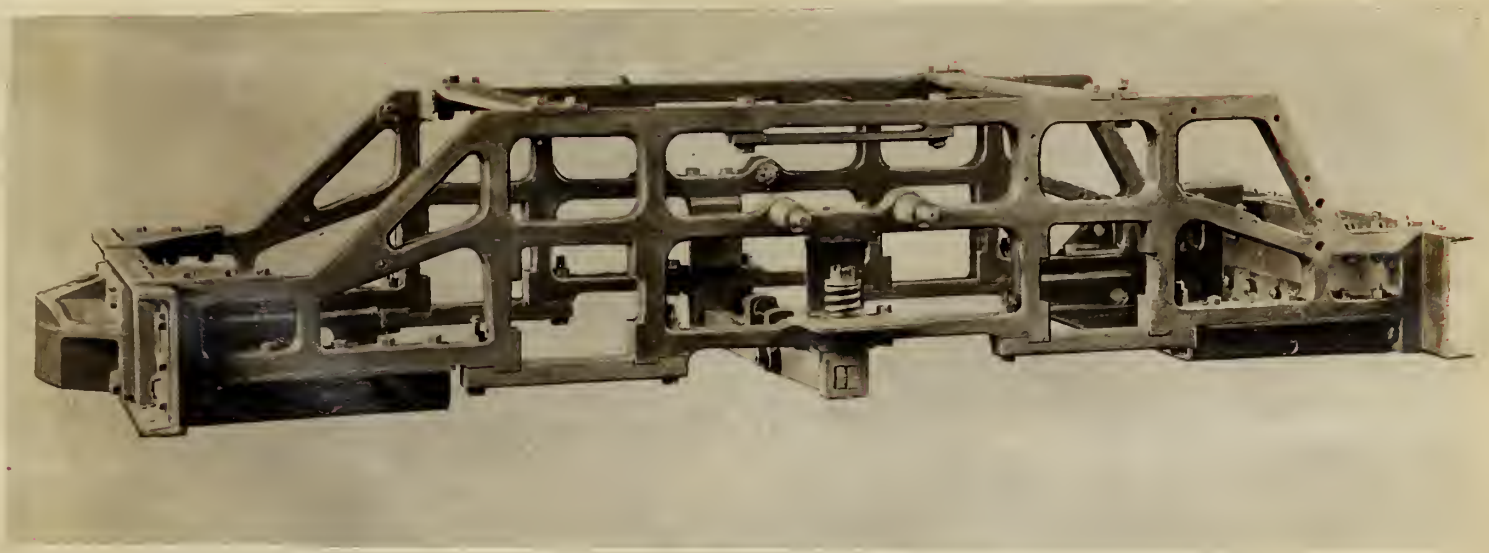


PLATE 14.

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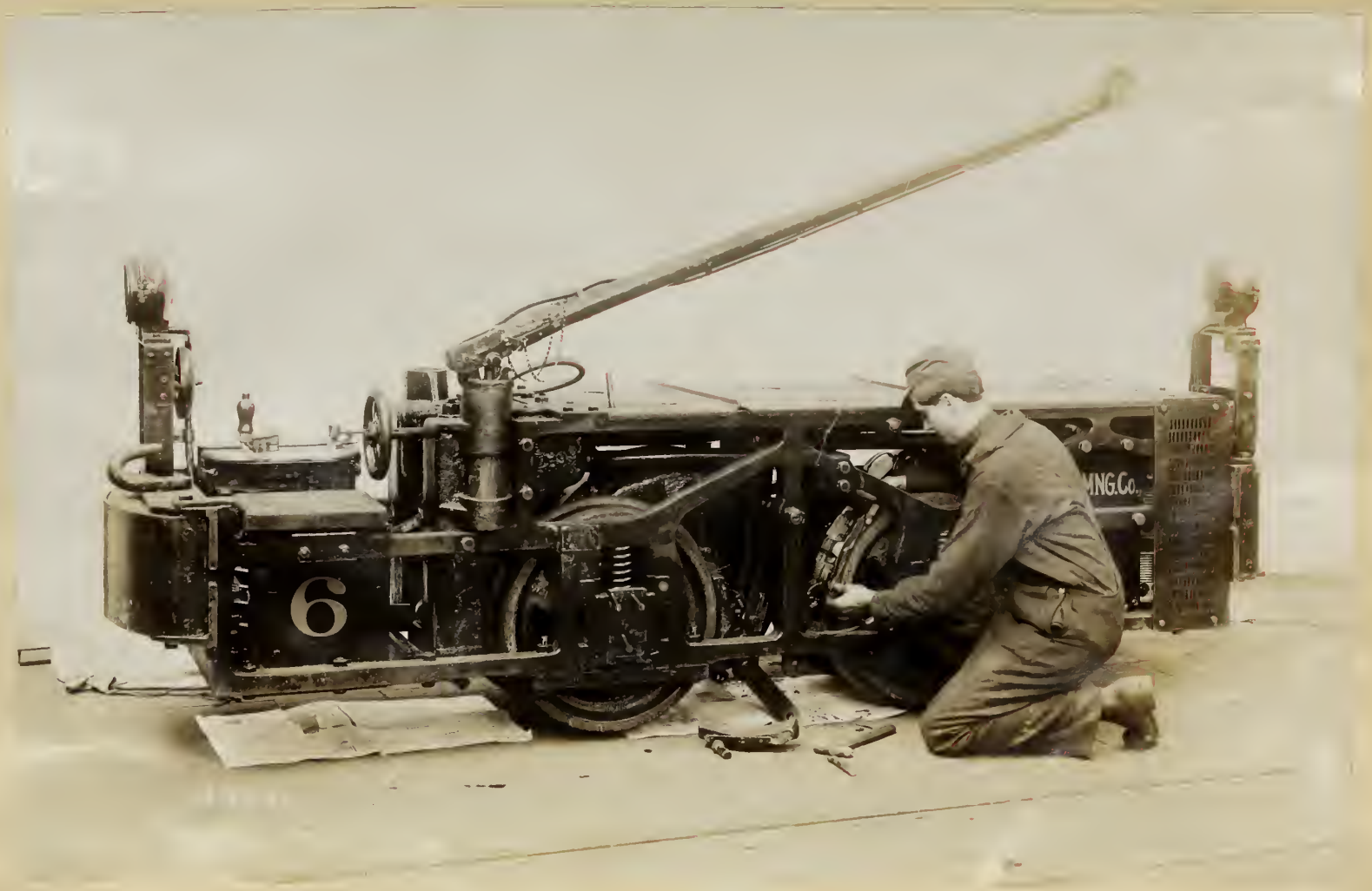


PLATE 15.

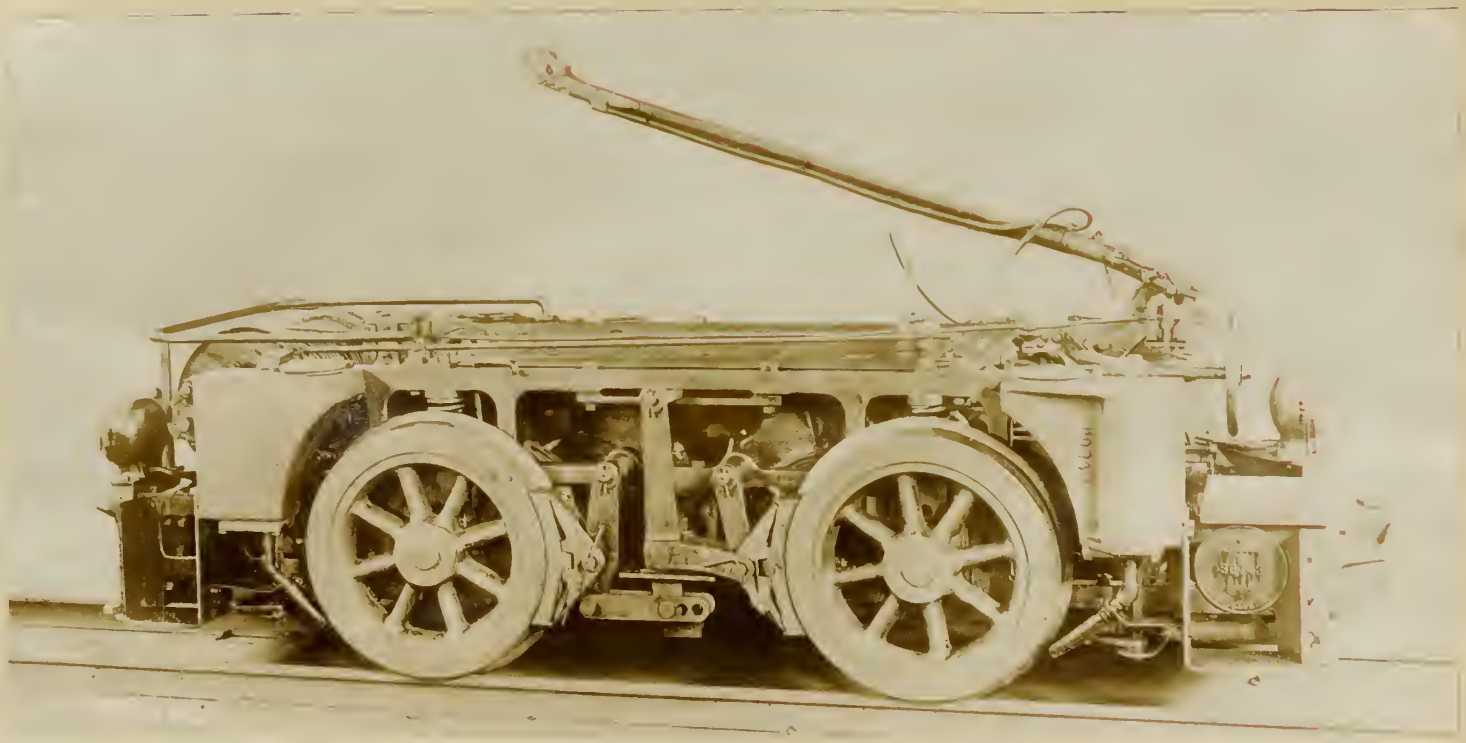


PLATE 16.

this type of frame beyond ease of inspection or repair, is that more perfect ventilation of the motors is obtained. Plate 15 shows how readily the brake shoes and heads are accessible in an outside frame locomotive with the bar frame. Plate 16 shows an inside frame locomotive and illustrates further the advantages of the open bar construction, in as much as the motor is very easily inspected and repaired through the openings in the frame.

Plate 17 shows the advantages of removable gibs which make it unnecessary to jack the locomotive up clear of the axle in order to remove the journal box. This is accomplished by means of a recess in the pedestals and a somewhat similar recess in the gib, so that by removing the pedestal cup below the journal, and jacking the locomotive up just sufficiently to relieve the pressure on the journal, the gibs can be dropped to a point where the upper flanges slide off. This makes it entirely unnecessary to disturb the suspension of the motor equipment to remove the journal boxes. Having discussed the advantages of this type of frame, I will now take up the disadvantages. In the first place, the equipment of the locomotive is more subjected to dirt, dust and moisture than in the armor type of frame. Secondly, the frame and parts are not as well protected, and in case of wrecks or collisions, the open frame locomotive might easily have foreign bodies thrust into the equipment of the locomotive through the open frame.

Wheels and Axles.

Chilled iron is used by most of the manufacturers for locomotive wheels, although steel tired or rolled steel wheels may be used. The cast iron wheels have a deep chill at the tread

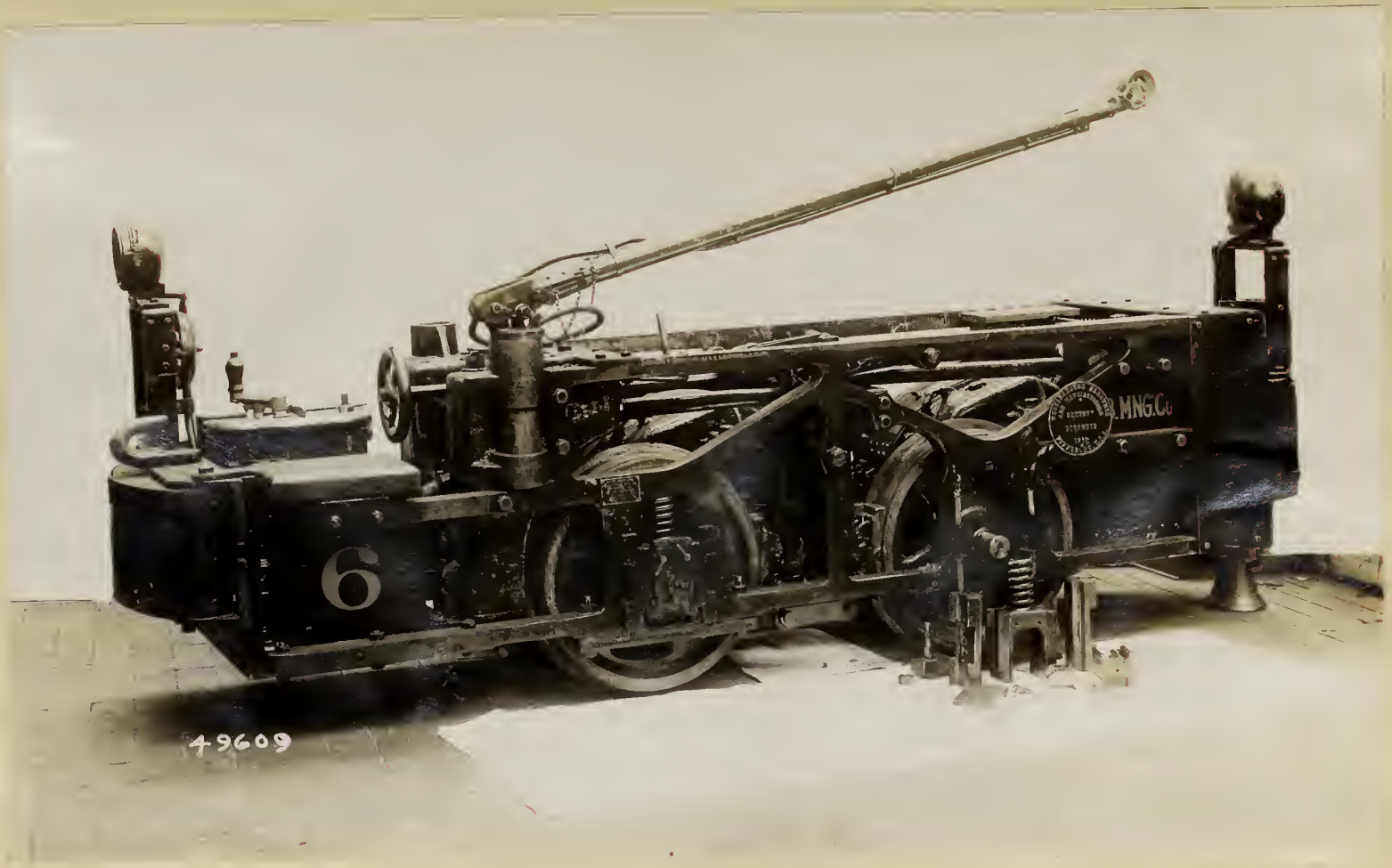


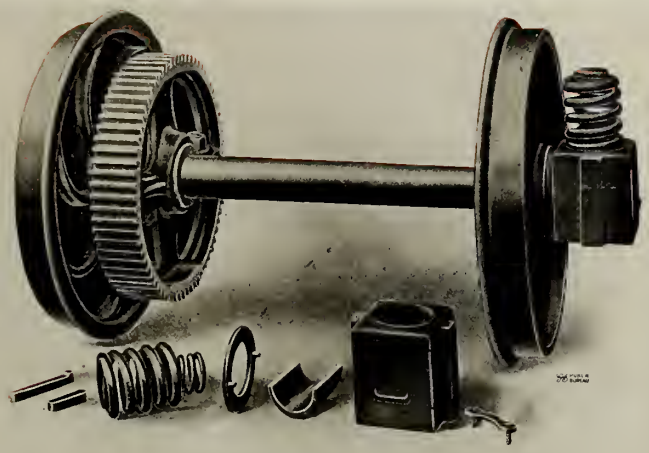
PLATE 17.

and are cast from a special grade of iron. Opinion differs as to the advantages of either chilled iron or steel tired wheels. The engineering staff of the General Electric Co. recommend the chilled iron tread while the Goodman Mfg. Co. recommend the steel tired wheel, their reason being that better tractive power is obtained. This I believe is undoubtedly true, but there is a question whether or not the additional tractive power obtained is great enough to warrant the use of a wheel, the life of which is much shorter than the chilled iron one. In the heavier locomotives, the Baldwin Westinghouse Co. found a decided advantage is gained in reducing the weight for a given draw-bar pull, or increasing the draw-bar pull with a given weight by the use of forged and rolled steel wheels or steel tired wheels. While the initial cost is slightly greater, this is more than offset by the longer life and the greater continuity in service.

M.C.B. standards are conformed with in the design of nearly all of the wheels, clearance between the flange and the rail being the same as in railway practice. Plate 18 represents the wheels, axles and brake shoes manufactured by the General Electric Co.

Journal Boxes and Springs.

Regular railway type journal boxes and springs are used by most of the manufacturers. The boxes have a removable lining of a special alloy, and are provided with oil cellars for waste The weight of the locomotive is supported from the journal boxes on heavy helical springs, the number of springs being dependent on the weight of the locomotive. Both the outside and inside journal



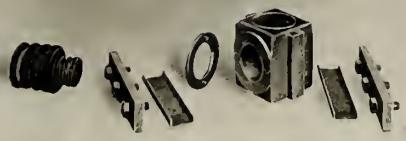
WHEELS AND AXLE OF OUTSIDE FRAME LOCOMOTIVE

BRAKE SHOE SHOWING THE SUPPORT OF THE SHOE PROPER
REMOVABLE BRAKE SHOE AND HEAD

PLATE 18.

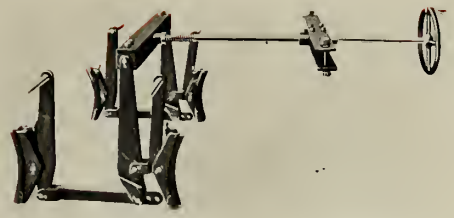
OUTSIDE FRAME JOURNAL BOX

INSIDE FRAME JOURNAL BOX

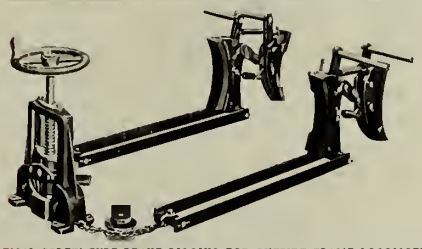


REMOVAL OF OUTSIDE FRAME JOURNAL BOX

PLATE 19.



HORIZONTAL SCREW TYPE BRAKE RIGGING



VERTICAL SCREW TYPE BRAKE RIGGING FOR OUTSIDE FRAME LOCOMOTIVE

VERTICAL SCREW TYPE BRAKE RIGGING FOR INSIDE FRAME LOCOMOTIVE

PLATE 20A.

boxes are illustrated in Plate 19. Roller bearings in place of oil cellars and waste, and the attendant babbit boxes have been placed on the market, and indeed may now be obtained on most of the locomotives if desired. I believe that in the storage battery locomotive the roller bearings are essential, however in the trolley type of locomotive the advantages gained do not pay for or warrant the additional cost of the roller bearings, in as much as a well babbited journal box works very nicely if only occasional attention is given it. Were the speed of the locomotives higher, thus increasing greatly the peripheral speed of the axle, the roller bearings would be almost a necessity, in order to reduce friction losses.

Brake Mechanism.

Brakes are usually extremely simple as shown in Plate 20A, but they are however, very powerful, being applied by direct lever action, operation being by means of a hand wheel and screw. In the Goodman Mfg Co's. locomotive the hand wheel is fitted to threads cut on either or both ends (single or double end control) of an equalizing bar passing along the top of the locomotiveand connecting the main levers for the brakes on two pairs of wheels. Other companies use much the same form of brake rigging, minor changes only being made to conform with the ideas of the engineers of the various companies.

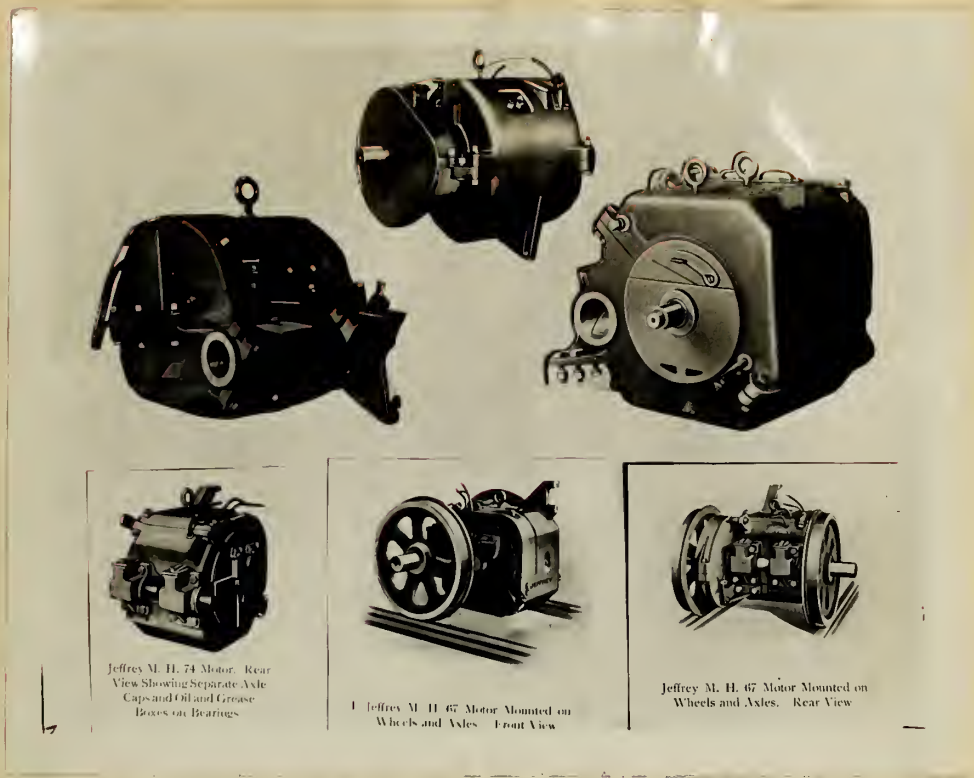
Sanding Devices.

All standard locomotives are equipped with suitable sanding apparatus, consisting of large sand boxes, cast integrally

with the frame or bolted on to the frame at either end of the locomotive. Sand pipes lead from these boxes so that sand is applied to the rails in front of the leading wheels, whether the locomotive is running backward or forward. By means of a separate lever provided for each direction the motorman can easily control the supply to the rail. The importance of adequate sanding can not be over emphasized. Probably 95% of the flat wheels have been caused by the wheels slipping on the rails when the current is suddenly applied to the motors in starting. When the rail is correctly sanded the resistivity of the wheel on the track is greatly increased, and the wheels therefore grip the rails, making it easy to start the trip, and at the same time reducing the amount of wear on both the rail and the wheels.

Motors.

The electric motors used in the electric mine locomotive of today are of the series wound enclosed steel type, and while varying in size, they are all of the same general construction. The frames of the motors are of soft cast steel and are split diagonally, the two halves being bolted together, (see Plates 20 and 21). In most of the motors the armatures are supported in separate malleable iron heads. These heads carry the armature bearings and are cored out for oil cellars. As regards sparkless commutation, the Westinghouse Co. have partly solved this problem by making the field frame of heavy steel castings into which are bolted laminated steel pole pieces, with a field coil for every pole, this insuring a uniform distribution of the magnetic field. The field coils are form wound, the conductors having asbestos or some other form



Jeffrey M. H. 74 Motor. Rear View Showing Separate Axle Caps and Oil and Grease Boxes on Bearings

Jeffrey M. H. 67 Motor Mounted on Wheels and Axles. Front View

Jeffrey M. H. 67 Motor Mounted on Wheels and Axles. Rear View

PLATE 20.

PLATE 21.

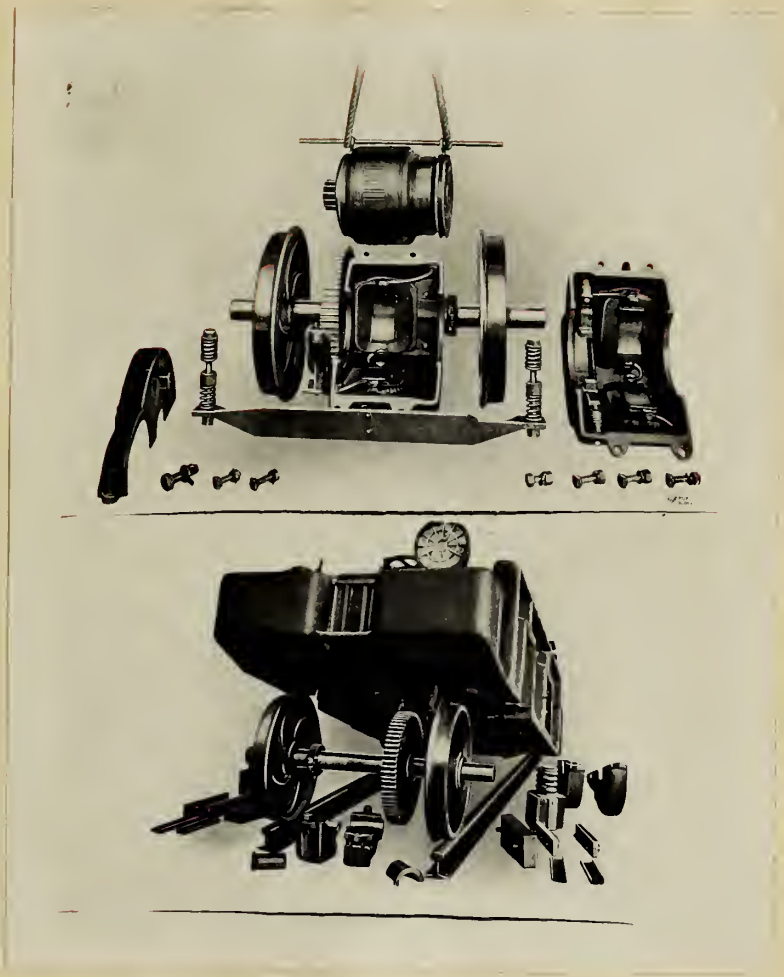


PLATE 22.

of insulation, so formed as to stand the maximum amount of jarring, and to withstand the severe heating attendant on heavy overloads, which in actual practice are likely to occur. Most manufacturers treat their coils with some form of preservative and then tape them so as to protect them against mechanical injury and moisture. The General Electric Co. has devised a very good form of motor suspension. As shown in Plate 20, the lower half of the motor frame carries both of the suspension lugs and the axle brackets. This form of construction makes the motor readily accessible for inspection or repair without having to dismount the motor suspension bar. Thus it may be perceived, that to make a repair on an armature, it is only necessary to remove the upper half of the motor frame. The importance of having a locomotive with the motors readily accessible can not be over emphasized, as both time and money are saved when repairs become necessary. A large handhole is provided on most motor frames over the commutator end, through which the commutator and the brushes may be cleaned, adjusted or inspected. At the pinion end of the motor a small hole is provided on the General Electric Co's. motors, through which gauges can be inserted and the amount of air gap determined. Thus when an air gap becomes excessive, it may be measured and steps taken to reduce it by taking up the wear on the bearings. On all of the large locomotives (over six tons), the motors are spring suspended, making the wear due to shocks or jars materially less. Plate 22 illustrates the accessibility and method of removing the armature and motor from the locomotive as manufactured by the General Electric Co.

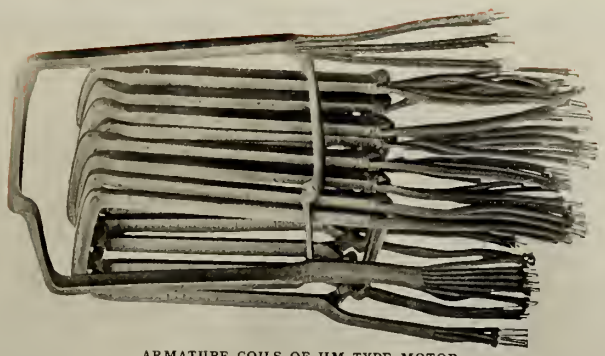
The armatures, as shown in Plates 21 and 23, are made of

soft steel laminations, held in place by malleable iron end plates. Ventilation is provided through the armature in order to secure proper cooling when the motor is in operation. The writer has seen motors in operation which were so hot that the locomotive frame was warm, hence the importance of cooling is very great. The mode of manufacturing the armature coils is of interest to us, in as much as it in part determines the efficiency of the motor. The armature coils are wound on forms. Several coils are bound together to form the unit or "poly" coil, which is insulated between the adjacent coils and is pressed to the exact shape in steam moulds. The coils are then covered with insulating material, and to insure protection against mechanical injury they are covered with tape filled with an insulating compound. The windings at both ends of the armature are covered with heavy canvas dressing securely bound into place. Heavy binding wire imbedded flush with the core surface is used to hold the coils securely in the slots.

The commutators are made of hard drawn copper bars, each bar being insulated from the other by mica, and clamped together by V-shaped clamping rings properly insulated by removable moulded mica sections.

Carbon brushes are employed on most of the modern motors, the sliding carbon type being the favorite. A shunt of flexible copper wire from the brush to the holder is advisable so as to prevent heating when a heavy current is used. (See Plate 24).

It is hardly necessary to discuss at any great length armature bearings. The two forms of bearings now in use are the ball bearing and the old style babbit bearing. The ball bearing armature is without doubt the better and more efficient one, and



ARMATURE COILS OF HM TYPE MOTOR

ARMATURE OF HM TYPE MOTOR

FIELD COILS OF HM TYPE MOTOR

PLATE 23.

although a little more expensive I believe its use is warranted when the high speed of the armature and the attendant friction are considered. The plain babbit bearing consists of a cast iron frame with a babbit lining, proper provisions being made for oiling. Care should be taken in the designing of a babbit bearing to provide a sufficient thickness of babbit metal so that it will not be worn down very rapidly, or so that should a hot box occur, through the negligence of the operator, the entire bearing will not be melted out. (See Plate 25).

Cast steel is used in the manufacture of the gears and pinions used in locomotive construction. The gears are of the split type securely bolted together over the axle key. The pinions are made of steel cut from a solid forged blank and tempered after cutting. They are keyed to the armature shaft and held in position by a large lock nut. All gears and pinions are encased in a malleable iron case divided into two parts on a plane passing through the center of the armature shaft and the center of the axle. The two halves are securely bolted together and a spring lid in the top half provided for babbiting the gears. The gear case is very well shown in Plate 20.

The controllers used on electric mine locomotives are, generally speaking, of the magnetic blow-out type, designed with a series parallel commutating switch in the reverse cylinder, which gives two economical speeds with a two-motor equipment. The main or reverse cylinders are interlocked so that the power has to be thrown off before the motors can be reversed.

When the controller is in the "off" position all parts of the motor equipment are "dead" and a special arrangement is in-

troduced to prevent "bucking" the motors to stop the trip quickly instead of using the brake. All contacts are or should be built heavily and the entire controller should be well ventilated in order to insure long life and few repairs. In the single end locomotive, the standard arrangement of control operates from one end of the locomotive. and is known as the single end control; in the double end locomotive, two controllers, one at each end of the machine are furnished, this arrangement being known as the double end control.

The rheostats are of the iron ribbon and cast grid types as used in standard locomotive practice. Each type has its advantages, and the choice depends largely upon the class of service for which the locomotive is to be built, depending upon size and voltage. A rheostat equipment consists of from three to eight or more boxes, each box containing from twenty-five to thirty-five grids. The grids are assembled on three steel tie rods which are mounted between pressed steel frames. These end frames are provided with foot lugs at both top and bottom so that a complete set of boxes can be bolted together to form a single unit. The grids are insulated from one another by mica washers and from the tie rods by heavy mica tubes. They have a large cross section; are very short, and are suspended at three points so that when assembled in the boxes there is absolutely no vibration. In the design of grids rugged construction, perfect ventilation and heavy insulation should be the dominant characteristics.

To protect the electrical equipment from short circuits and injurious over-loads, all locomotives should be equipped with either fuses or circuit breakers, or better both. The magnetic

BRUSH-HOLDERS OF HM TYPE MOTORS

AXLE AND ARMATURE LININGS OF HM TYPE MOTOR

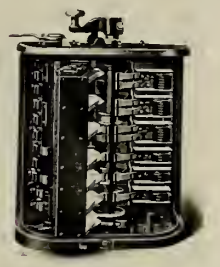
PLATES 24 & 25.

CIRCUIT BREAKER
WITH COVER REMOVED

CAST GRID RHEOSTAT

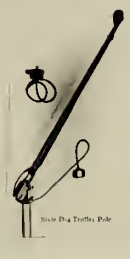
ENCLOSED CARTRIDGE FUSE

Jeffrey Trolley Wheel, Harp and Socket, designed especially for Mine Service



R106 CONTROLLER

FORM D-4 MINE TROLLEY



Style D-4 Trolley Pole

PLATE 26.

circuit breaker is probably the best in that its use eliminates the inconvenience of having to fit new fuses into the boxes when a fuse burns out. It is however more expensive, and where cost is an important consideration, cartridge fuses may be used. Grids, circuit breakers and fuses are illustrated in Plate 26.

Trolley poles are generally made to fit the local conditions under which the locomotive is to operate. However all trolleys are similar to the types shown in Plate 26, these being those used by three of the large manufacturers of electric locomotives, namely, the General Electric Co., the Baldwin Westinghouse Co., and the Jeffrey Co. The trolley wheel is mounted in a swivel harp which permits it to allign itself with the trolley wire, irrespective of the direction of the pole. The pole is made of hard wood and the lower end is inserted in a swiveled base which fits into sockets on either side of the locomotive. The force of the compressed spiral spring is so applied to the pole that the pressure of the trolley wheel against the wire is approximately uniform throughout the limits of vertical variation and the swivel harp permits of a large lateral variation of the wire. The trolley cable terminates in a contact plug which fits into a receptacle placed on each side of the locomotive so that the change from one side to the other is readily effected.

Gathering Locomotives.

Gathering locomotives, as the name implies, are used for gathering the cars and hauling them from the rooms to the main entry. In small mines the gathering locomotives areused also for the main haulage locomotives, or mules are used to haul the cars

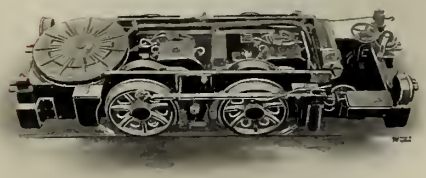
from the face to the main entry, but in large mines the gathering locomotive operates only from the rooms to the main entry.

The gathering locomotives are equipped with cable reels for carrying the current from the trolley wire in the main entry to the rooms to which the locomotive is to travel. The General Electric Co. produced the first practical gathering locomotive in either 1902 or 1903, after they had demonstrated that electric locomotives for gathering were cheaper to operate than mule haulage would be, especially in mines where the coal seam was very thin and the height would have to be increased considerably to accommodate mules, whereas, were locomotives used, the roof could be very low.

Power for operating the cable reel was furnished by chain and sprocket drive from the locomotive axle. A number of locomotives are still in operation with this form of drive, but because of the fact that clutches, shifting levers, or friction discs are necessary this type has been largely discontinued.

In 1907 the General Electric Co. brought out a motor driven reel. This reel was driven through double reduction gearing by a small vertical series wound motor. The reel proper is supported by the motor frame and rotates on a ball bearing between the main gear and the top of the motor. The motor is connected directly across the line in series with a permanent resistance which protects it from being burnt out by a heavy rush of current when the locomotive is standing still. The motor is so designed that it may be operated continuously without overheating. Most of the reels are equipped with 500 feet of flexible heavy insulated cable. The inner end of this cable is connected to a collector ring on

SEVEN-TON GATHERING LOCOMOTIVE



INTERNAL ARRANGEMENT OF SEVEN-TON GATHERING LOCOMOTIVE DESIGNED FOR LOW VEIN WORK

FOUR-TON GATHERING LOCOMOTIVE

PLATE 27.

CABLE REEL MOTOR WITH REEL REMOVED

PLATE 28.

the under side of the reel and the outer end is fitted with a copper hook for attaching to the main entry trolley wire. On leaving the entry the cable is hooked over the trolley wire, and as the locomotive moves up towards the room, the reel motor virtually becomes a series generator, its counter electromotive force producing a torque sufficiently great to produce a tension in the cable which causes it to pay out evenly and to drop on the road without kinks, this being very conducive to longevity of the cable. The motor and gearing are so designed that the motor has a tendency to produce a peripheral speed at the rim of the wheel that is higher than the linear speed of the locomotive, so that there is a constant tension in the cable, which insures it being wound compactly. Plate 27 illustrates three gathering locomotives built by the General Electric Co., the center plate and Plate 28 showing the manner in which the reel and motor is mounted. As will be seen, it is mounted on two straight supporting bars bolted to the locomotive side frames. These bars with the cable guides and the protective resistance of the motor are the only extra parts used, the reason for this being primarily to avoid complicated parts, and secondly to make it possible to convert any standard locomotive into a gathering locomotive.

The wiring connections of a standard gathering locomotive are shown in Plate 29.

The gathering locomotives manufactured by the Goodman Mfg. Co. of Chicago, differs very little from the locomotives described above. The Goodman Mfg. Co. although they now build a two-motor type of locomotive, advocate a single motor type. The reason advanced for this is that in gathering work, lower

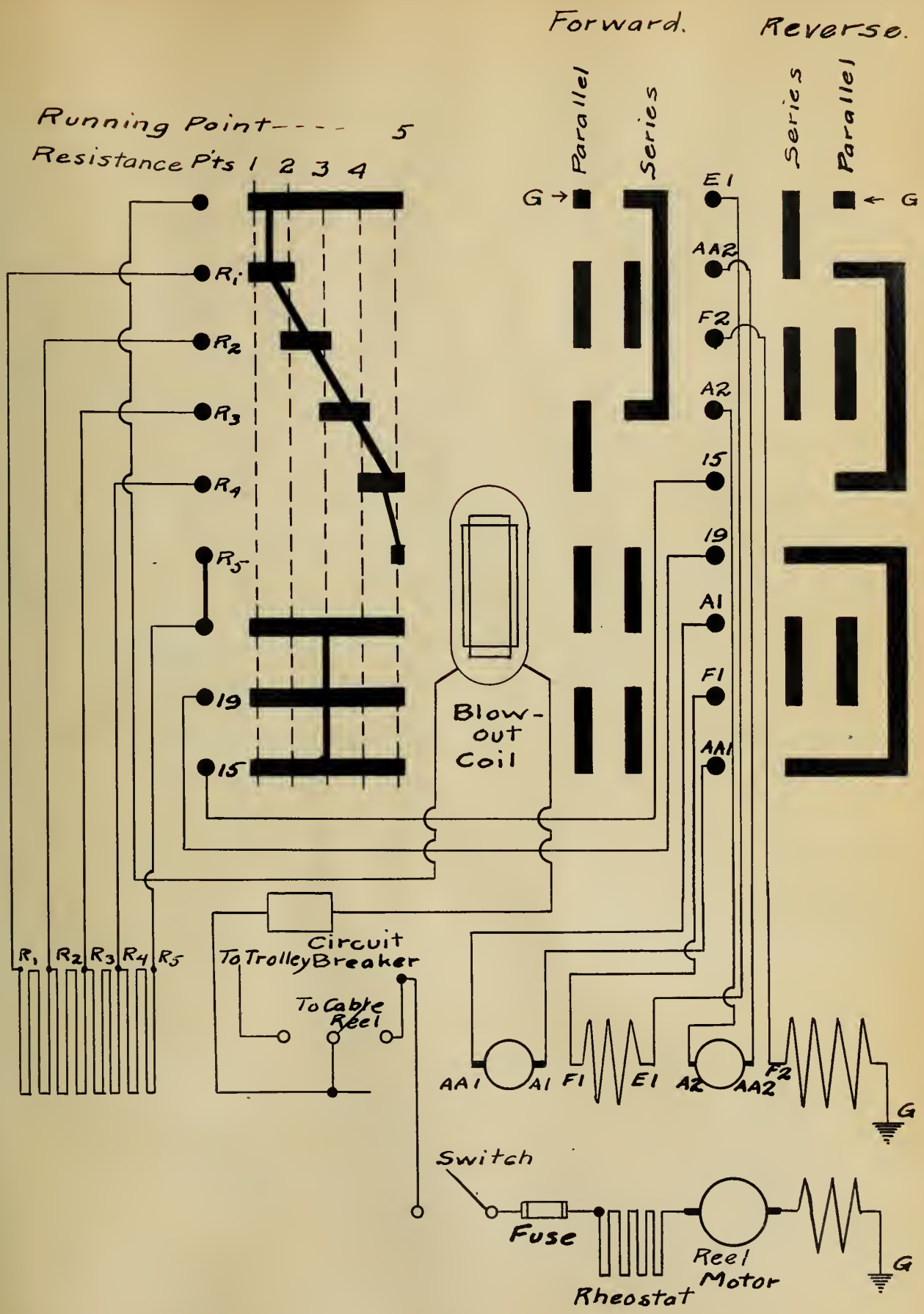
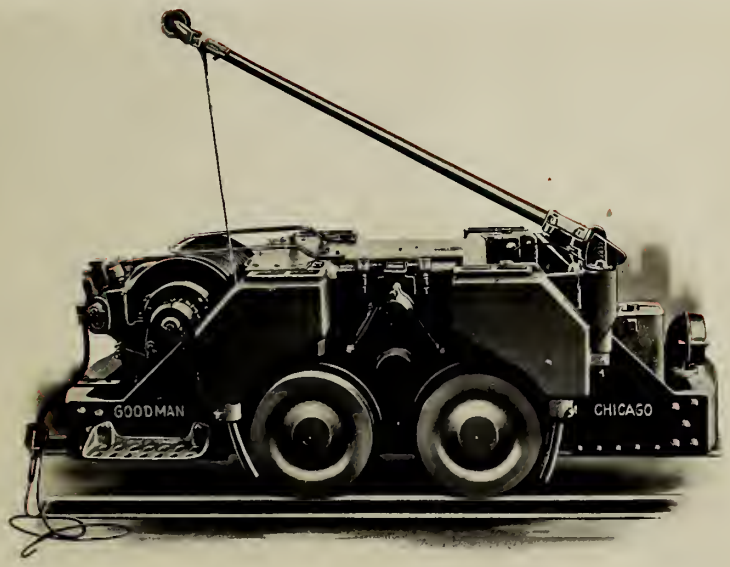

Forward.
Reverse.
Running Point----
5
Resistance P'ts 1 2 3 4
Parallel
Series
Series
Parallel
G
G
E1
AA2
F2
A2
15
19
A1
F1
AA1
R1
R2
R3
R4
R5
19
15
Blow-out Coil
Circuit Breaker
To Trolley
To Cable Reel
R1 R2 R3 R4 R5
AA1 A1 F1 E1 A2 AA2 F2
G
Switch
Fuse
Rheostat
Reel Motor
G

Plate #29

power is required, the locomotive must necessarily be smaller, and therefore it is more advisable to build a locomotive with one large motor, making generous room for all parts, than to crowd two motors into a relatively small space. The Goodman Mfg. Co. build one type of gathering locomotive (see Plate 30) in which a mechanical reel is used. Here the reel is driven by a chain, a sprocket being attached on the axle and another on the reel. This type is inferior, I believe, to the motor drive because of the fact that a spring is necessary in winding up the cable to keep the latter wound evenly on the reel; furthermore the chain adds an additional mechanical drive to keep in repair. However for cheapness and for extreme simplicity it is desirable.

Where a more expensive equipment is desired, the Goodman Mfg. Co. employ a motor to drive their reel, similar in construction to the General Electric Co's. motor. The third type of reel drive is the spring. This reel drive as shown in Plate 31 is a self contained device and operates quite independently of the locomotive motors or mechanical parts. Its construction is as follows:- inside of the drum of the reel are nested several heavy steel springs connection to operate much after the fashion of a window shade roller. When the cable is drawn off as the locomotive advances, the springs are wound up; when the locomotive returns, the cable is automatically reeled in as the cable springs are uncoiled. Thus the cable is always kept taut whether the locomotive is running forward or backward or is standing still. The spring reel has the advantage over the mechanical reel in that sliding or slipping of the locomotive wheels can not affect the action of the reel. Provision is made so that the cable may be wound up without



Type 1600 Gathering Locomotive with Mechanically Driven Cable Reel.
Patented: Aug. 22. 1905; Dec. 10. 1907

PLATE 30.

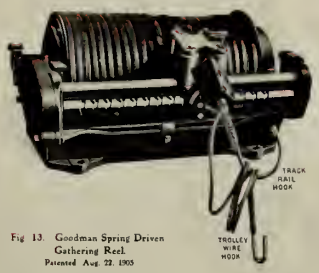


Fig 13. Goodman Spring Driven Gathering Reel.
Patented Aug. 22. 1905

Fig. 9. Goodman Electrically Driven Gathering Reel —End View.
With 300 Feet of Duplex Cable
Patented Aug 22 1905

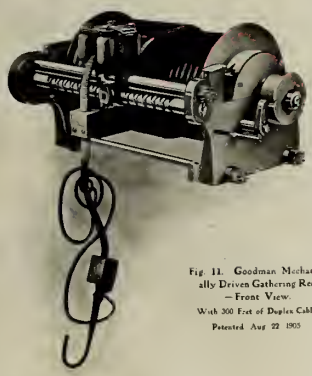


Fig. 11. Goodman Mechanically Driven Gathering Reel —Front View.
With 300 Feet of Duplex Cable
Patented Aug 22 1905

PLATE 31.

operating the locomotive. The spring reel has a further advantage in as much as it may be removed from one locomotive and transfered to another locomotive as conditions in the mine demand; or if a gathering machine is not needed in the development of a new part of the mine, the reel may be used in some other part of the mine, or it may be stored away, thus keeping it in better working order.

Both the Jeffrey Co. and the Baldwin Westinghouse Co. make use of much the same types of reels as in the locomotives described above.

Regarding the superiority of the electrically driven reel over the spring and the mechanical types, I would say that the electric drive is most desirable, in as much as it is a self contained unit; the motor when acting as a generator sets up a torque which causes the cable to pay out more evenly than the other types of reels do; low voltage and mining conditions affect the reel very little; and it requires very little power to operate it. The mechanical reel is desirable only when costs must be closely considered, the inherent limitation of all reels of this type being that it fails to work when the wheels of the locomotive slip. The spring driven wheel I consider more efficient and desirable than the mechanical reel, inasmuch as it is self contained and is very simple. It has one drawback in as much as the spring may get out of adjustment, and further the wear is also very great in the springs and bearings of a reel of this type.

The current control of an electric gathering locomotive is quite an important consideration. A locomotive fitted with a gathering reel and one trolley pole has two means of receiving its power. If two trolley poles are used, which is often the case, the

sources of power are increased to three. If all three sources are in a fixed connection with the controller, their electric parts will all be alive whenever one of them is in use. It is therefore necessary to use a three way switch, which makes it possible to use only one source of power. Plate 32 illustrates a three-way switch manufactured by the Goodman Mfg. Co.

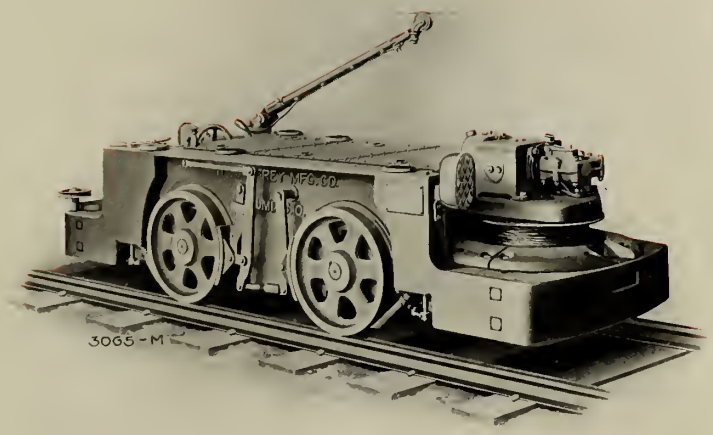
The Crab Locomotive.

The crab locomotive is essentially the same as the regular type of main haulage locomotives, slight changes being necessary for the reception of the crab device and its accesories.

The crab locomotive gets its name from a power driven crab or drum mounted on the forward end of the locomotive (see Plate 33). A flexible steel cable of the required length is mounted on the drum, and it is used to haul the cars from the rooms to the main entry. As shown in Plates 34 and 35, when a car is to be hauled from a room, the locomotive is stopped in the entry near the room mouth. The trip man drags the rope up into the room and attaches its end onto the car, and then signals the motorman who starts the crab, and this pulls the car to the main entry, from whence the locomotive hauls them to the shaft bottom. The motor which drives the crab is very compact, and the drive is through a friction device which permits the cable reel to slip under excessive strain and thus prevents damage to the car or motor should the motorman fail to stop the crab before a car reaches the locomotive.

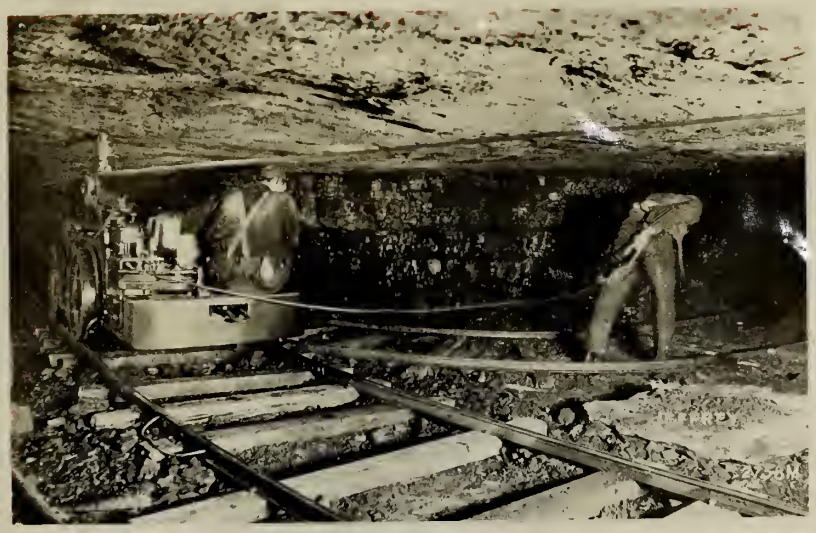
Fig. 15. Goodman Three-Way Switch Open.

PLATE 32.



A 5-Ton Jeffrey Crab Locomotive with Outside Wheels.

PLATE 33.



JEFFREY 5-TON CRAB LOCOMOTIVE IN OPERATION
The locomotive stands on the entry while the trip rider carries the cable into the room, as shown, and attaches it to the car.

PLATE 34.

Rear View—Showing the Crab Device Pulling a Loaded Car from a Room.

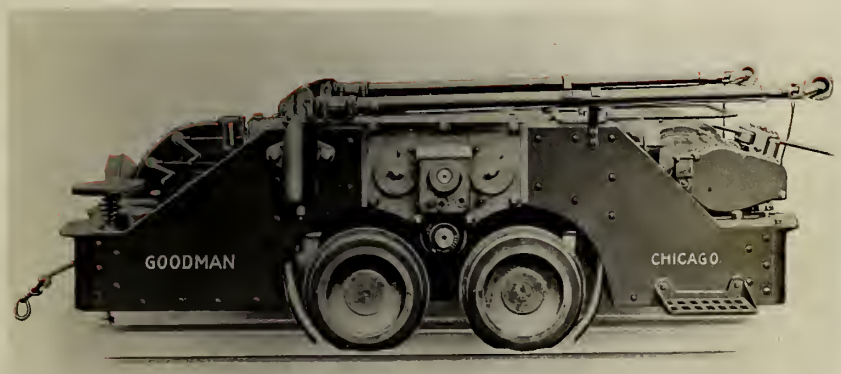
PLATE 35.

The Universal Locomotive.

The Goodman Mfg. Co. realizing the tremendous advantage of the crab and also the gathering reel, conceived the idea of building a locomotive embodying both ideas. The result was the production of the so-called universal machine as illustrated in Plate 36. The "steel rope" drum is either mechanically or electrically driven and the electric cable reel is driven by either the electric motor, spring or mechanical arrangement. The adaptability of the steel rope reel can not be over emphasized as its sphere of usefulness includes its usage in producing a strong pull wherever desired.

Rack-Rail Locomotives.

Hauling a trip of cars on comparatively level track is relatively easy, it being necessary to overcome only the resistance of the train and track. On steep grades however, upgrade haulage is very difficult, in as much as the locomotive not only has to overcome the resistance attendant to level track haulage, but it also has to virtually lift the whole train more or less gradually depending upon the pitch of the grade. With grades up to 15% the rack-rail system of electric locomotive haulage has worked admirably. In this system of haulage no dependence is placed upon track adhesion for the pulling power, said power being obtained by means of a sprocket meshing into the rack-rail, the sprocket being driven by the electric motor which is geared to the locomotive axle so that traction may be used on level hauls. In case this combined type is used, a clutch is generally placed on the axle so that the sprocket runs loose when the locomotive is being used



Goodman Type 2100 "Universal" Gathering Locomotive—Side View.
With Spring Driven Electric Cable Reel and Mechanically Driven Steel Haulage Cable Drum
Patented: Aug. 22. 1905. Dec. 10. 1907.

PLATE 36.

on level hauls. In the plain rack-rail type the sprocket remains stationary on the axle all the time and the locomotive wheels serve only as carriers of the locomotive. Plate 37 illustrates the two types of rack-rail drive. The single motor type of locomotive construction is used by the Goodman Mfg. Co. in this type of locomotive (see Plate 38).

The track for Goodman rack haulage requires that the rack-rail be laid on the ties between the regular track rails. When possible it is advisable to lay the rack-rail centrally between the two rails. If the track is narrow, the rack-rail may be placed five inches off center. The rack-rail is made in regular sections 16 feet long and drilled at the ends with suitable holes for bolting on the fish plates by means of which the rack is made continuous. There are two types of rail construction designed for live rack-rail, and dead rack-rail service. The live rail, which is intended to carry the current for operating the locomotive is supported entirely in wood, for both protection and insulation (see Plate 39). The dead rack-rail is supported in iron chairs as shown in the lower half of Plate 39. In both types of construction a wood base stringer is used, spiked firmly to the ties. The rack-rail is set high enough to provide clearence for the points of the sprocket of the locomotive in passing over the track rails at turn-outs. Gaps in the rack-rail itself are necessary therefore in order to let the wheels of the locomotive cross at such turns. On locomotives in which the live rack-rail is used only, the locomotive will coast across such gaps in the rail for short turn-outs. This however is not as satisfactory as is the dead rack-rail and the combination rack-rail and traction locomotive. The wiring of the

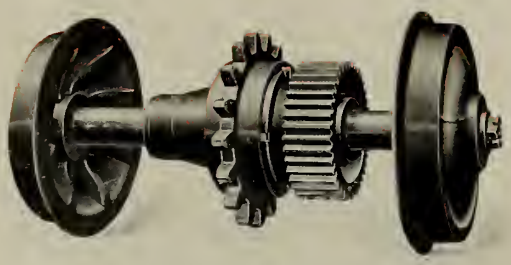


FIG. 1.

Wheels, Axle and Driving Sprocket of Goodman Plain Rack Locomotive.

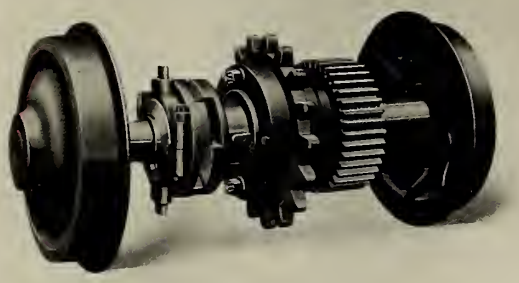
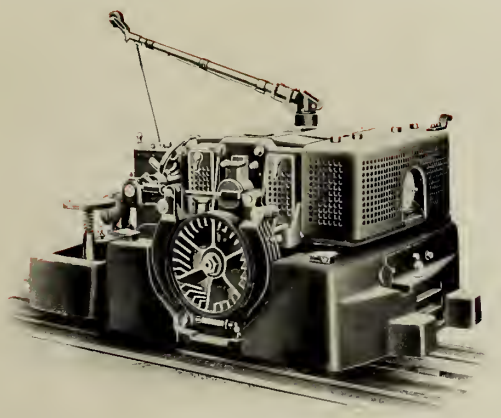


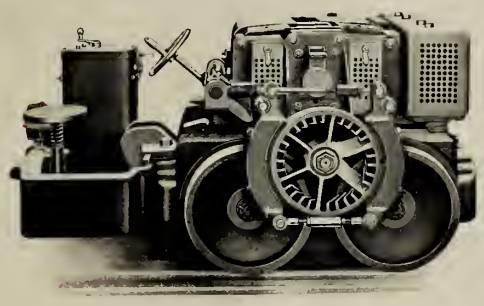
FIG. 2.

Goodman Combination Rack Locomotive Driving Elements, Showing Clutch for Operating Traction Drive.

PLATE 37.



Narrow Gauge Type F. 100-Hp. Goodman Plain Rack Locomotive.
Equipped with Trolley Pole—For Operating on Dead Rack Rail



Type F. 100-Hp Goodman Plain Rack Locomotive—Brake Side
No Trolley Pole—To Operate on Liv. Rack Rail

PLATE 38.

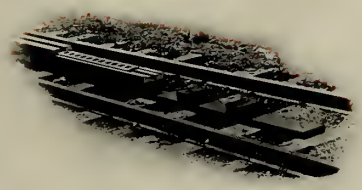


FIG. 3.
Goodman Live Rack Rail Track Construction.

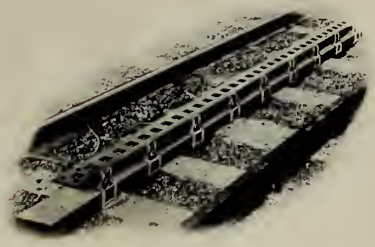


FIG. 4.
Goodman Dead Rack Rail Track Construction

PLATE 39.

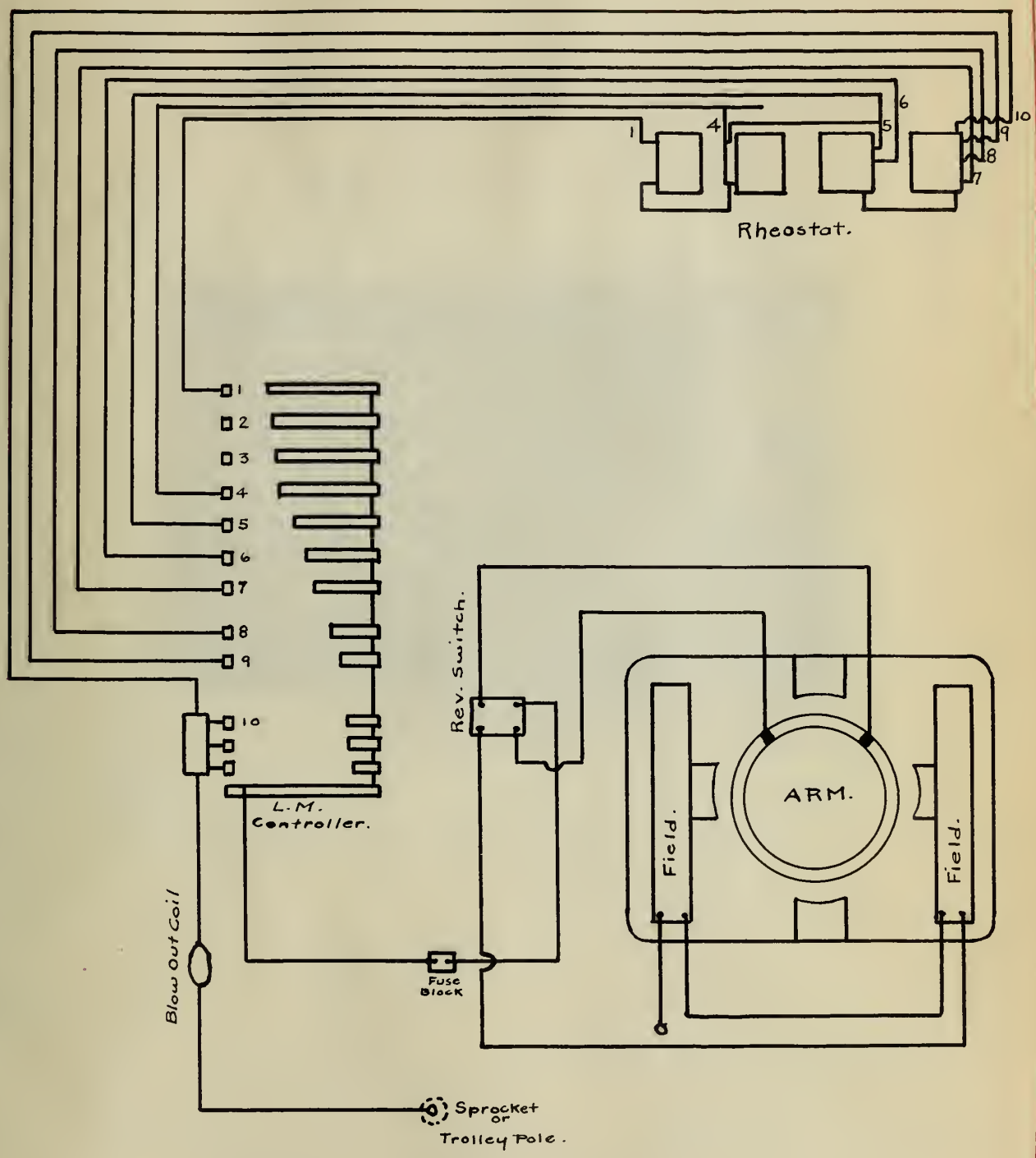
plain 100 horse-power unit is shown in Plate 40. The weight of this machine is five tons, and for combination rack-rail and traction working, the weight is six tons. The minimum track gauge with a locomotive with outside wheels is 35 inches. If the wheels are placed inside the frame, the minimum gauge is 18 inches. Plate 41 illustrates one of the plain rack-rail locomotives climbing a 16% grade. The advantage of the rack-rail locomotive over the traction locomotive on grades is most strikingly shown by the following table:-

Effect of Difference in Locomotive Weight on Hauling Capacity of Traction Locomotive and Goodman Rack Locomotive of Equivalent Power.

15 Ton Traction Locomotive-100 H.P. Rack Locomotive 5 ton.

- - - - - - - - - - -

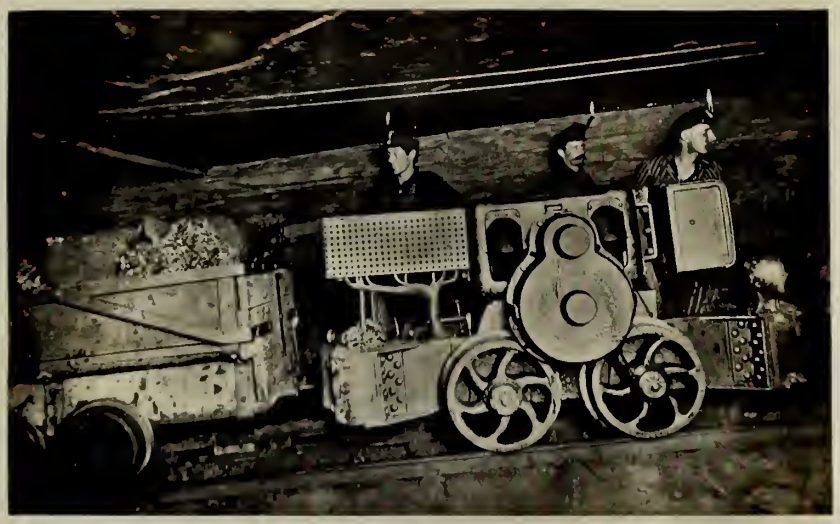
Grade	Draw Bar Pull		Train Load Hauled. Resistance 2%. Pounds Gross		Loaded Cars of 5000 lbs. gross weight		Gain in Train Load by Rack Locomotive as compared to Traction.
%	Tractive	Rack	Tractive	Rack	Trac.	Rack	%
Level	6000	6000	300000	300000	60	60	Equal
1	5700	5900	190000	197000	38	39	3.7
2	5400	5800	135000	145000	27	29	7.4
3	5100	5700	102000	114000	20	22	11.8
4	4800	5600	80000	93300	16	18	16.7
5	4500	5500	64300	78600	12	15	22.3
6	4200	5400	52500	67500	10	13	28.6
7	3900	5300	43300	59000	8	11	36.3
8	3600	5200	36000	52000	7	10	44.5
9	3300	5100	30000	46300	6	9	54.3
10	3000	5000	25000	41700	5	8	66.7
12	2400	4800	17100	34300	3	6	100.0
13	1500	4500	8800	26500	1	5	200.0
20	0	4000	0	18200	0	3	-----



WIRING CONNECTIONS

RACK RAIL GATHERING LOCOMOTIVE.

PLATE 40.



Type B. 80-Hp. Goodman Plain Rack Locomotive Climbing 16 Per Cent Grade.
Locomotive Pulls 25-Ton Trips Up This Steep Main Entry Slope.

PLATE 41.

Storage Battery Locomotives.

The use of mine storage battery locomotives is still very limited, only a few large mining companies having adopted them. The Jeffrey Co. of Columbus Ohio, the General Electric Co. of Schnectady N.Y., the C.K.Davis Co. of Detroit, the C.W.Hunt Co. of N.Y., and the Alton Car and Mfg. Co. of Cleveland Ohio, are the principal builders of this type of locomotive. The application of the storage battery locomotive has been to gathering work. One of the General Electric Co's. machines was recently installed in the mines of the Philadelphia and Reading Coal and Iron Co. This locomotive is equipped with two 85 volt motors and a controller of the same type as is used in overhead trolley locomotives. The batteries employed are Type A-8, Edison 70 cell, and have a 300 ampere hour capacity, with a discharge of 60 amperes for five hours. They provide at the full rated draw-bar pull, namely 1000 pounds, and the normal speed namely $3\frac{1}{2}$ miles per hour, for a mileage of nine miles with one charge of the batteries. The machine is equipped with an ampere hour meter, indicating the amount of charge and discharge, so that the operator may know at all times the capability of his machine.

The frame consists of steel channel sides and steel plate ends, carefully bolted at the joints, and held together rigidly by bolts and steel angles. The end plates are faced with wooden bumpers to which suitable couplers are attached. A seat for the operator is provided in the rear. The cast steel pedestal jaws, which carry the journal boxes, are securely bolted to the lower web of the channel side frames. The journal boxes are made of cast

steel and are of special design. Roller bearings are employed in order to insure efficient mechanical transmission, a point which must not be overlooked especially where the economy of power consumption is so affected. The entire weight of the locomotive is supported from the journal boxes by two coiled springs.

The wheels are made of chilled iron and are pressed on, and are securely keyed to the axles which are made from special steel, case hardened at the journals.

The motors are series wound, totally enclosed and are comparable to the familiar automobile type of motor. They have high efficiency, large over-load capacity, and operate with practically sparkless commutation. The high efficiency is obtained by designing the motor with a small air gap, and running the iron at low densities. By reason of the latter provision, the speed and torque characteristics are steeper than in ordinary series motors, thereby tending to limit the over-load which can be thrown on the batteries. The armature shaft rotates in ball bearings, friction losses therefore being very slight, and bearing wear therefore almost negligible.

The controller is of the drum type, similar to the type used in overhead trolley locomotives, changes being made to accomodate only the lower voltage.

The motors are mounted as follows:- one motor is mounted on each axle in a cast steel suspension cradle, one side being supported on the axle bearings and the other side spring being suspended from the locomotive frame, in accordance with standard locomotive practice. The motors drive the axles through double reduction gearing, an intermediate shaft, supported in the bearing

housing and cast integral with the suspension cradle, carrying the intermediate gearing. As slow speed service is ordinarily requiredof a storage battery locomotive, the use of double reduction gearing affords such speeds with minimum rheostatic losses; and due to the large gear ratio from armature shaft to wheel tread, high tractive efforts are obtained at comparatively small current imput.

Brake tension is effected by means of a square threaded brake spindle. A square threaded nut travels on the spindle and carries an equalizing bar to the end of ehich are connected chains leading from the brake levers. This device admits of locking the brakes automatically without the use of pawls or rachets, in any position left by the operator.

The specifications of this locomotive as given by the builder are as follows:-

Total weight- 8000 pounds.

Length over all- 8'9".

Width over all- 5'3".

Height over platform- 2'4".

Height over battery compartment- 3'9".

Wheel base- 44".

Diameter of wheels- 20".

Track gauge- 44".

Rated D.B.P.- 1000 pounds.

Speed at rated D.B.P.- $3\frac{1}{2}$ m.p.h.

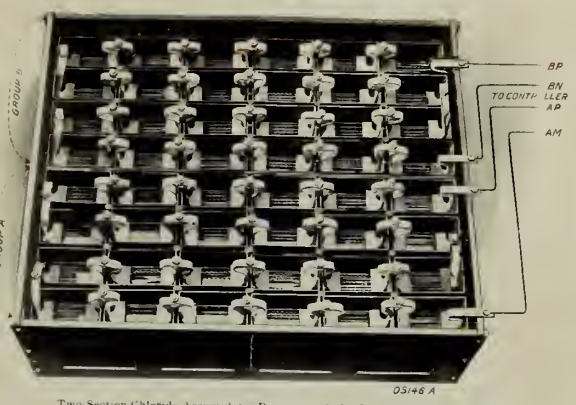
The batteries are designed for this particular service and are of rugged construction, the plates being made very strong-

yet of such construction as to make them very efficient. The cells are grouped in eighteen trays, protected in a wooden case.

Plate 42 is an illustration of the batteries used in the above locomotive, while Plate 43 illustrates one of the types of mine storage battery locomotives built by the Jeffrey Co.

Regarding the choice of "Edison", "Exide", "Iron-Clad", or "Accumulator" cells, I believe the Edison is the best as far as the question of mileage and life is concerned. They are however, very expensive and the charging efficiency is low. They are nevertheless without doubt the best cells to use in storage battery locomotives. The "Exide" and other cells similar to it have a very high charging efficiency but their mileage and life are not as great as those of the Edison, and are therefore cheaper cells.

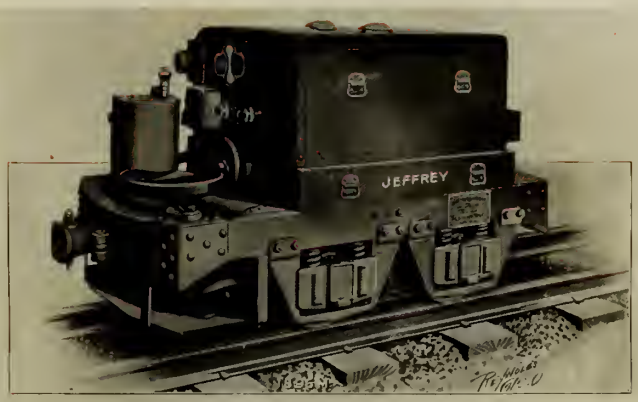
The ideal storage battery locomotive, I believe, would be one equipped with two motors, connections to be made for both series and parallel circuits. It should be equipped with a trolley pole so that it could operate on the main haulage way using 110 volts, motor then being in series, each motor taking 55 volts; when it is desired to operate the machine as a storage battery machine it would only be necessary to throw the motors in parallel and operate them on the 55 volt storage battery circuit.



Two-Section Chloride Accumulator Battery, with the Cover Removed.

Edison Storage Battery, with the Cover Removed.

PLATE 42.



Jeffrey 2½ Ton Storage Battery Locomotive

PLATE 43.

Part III.

Rating and Performance.

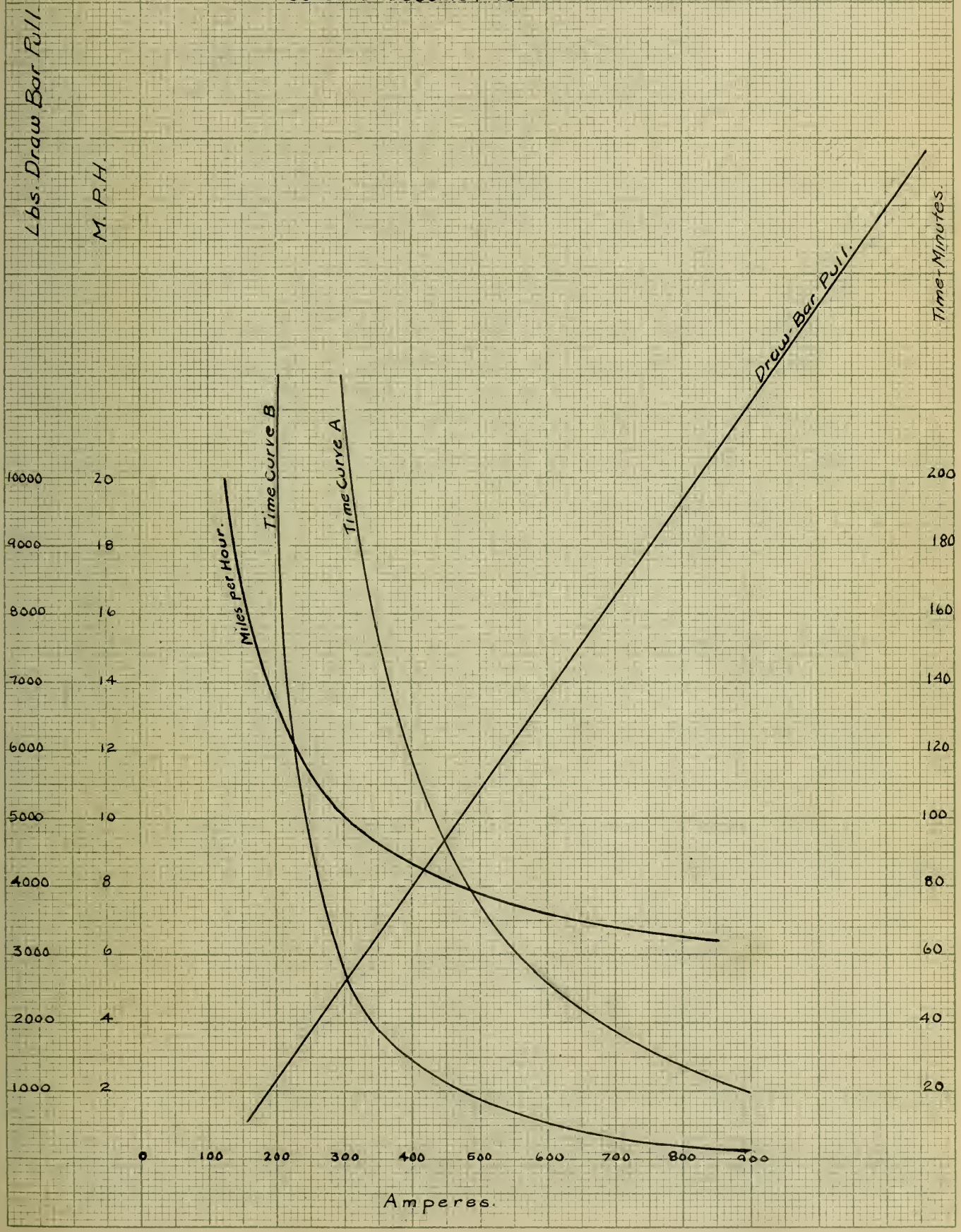
Maximum Draw-Bar Pull Connected and Unconnected Axles.

The maximum draw-bar pull which can be obtained from any electric locomotive depends upon the weight of the locomotive and the cohesion between the wheels and the rails. In giving a normal and nominal rating, the manufacturers assume approximately one-fifth of the weight of the locomotive as the draw-bar pull. But this statement of draw-bar pull does not cover completely the performance of the electric locomotive, for the motor becomes warm when the load is applied, and soon it is warmer than the surrounding air, and the heavier the load the faster is the heating. In establishing some satisfactory rating for electric motors it is necessary to take into consideration this heating effect, and consequently a limiting temperature must be determined up to which the motor may operate without injuring the windings. Most electric locomotive manufacturers have rated their locomotives on a 75 degree Centigrade rise from a temperature of 25 degrees Centigrade in one hour; that is, a locomotive when operating under normal conditions for one hour will have a rise of 75 degrees C. in the motor. In the accompanying curves, Plate 44A the figures are taken from tests of the Baldwin Westinghouse Co. The locomotive was a 36,000 pound standard mine locomotive. Curve "A" is a time-draw-bar pull curve and shows the length of time the locomotive will give different values of draw-bar pull with a temperature rise of

PLATE 44A.

Performance Curves.

36000 lb. Locomotive



U. OF I. S. S. FORM 3

seventy-five degrees Centigrade when starting cold. Time curve "B" shows the length of time it is safe to use the locomotive at the various values of draw-bar pull without injury to the motors,but starting with the motor temperature at seventy-five degrees Centigrade instead of starting cold.

The speed curve shows the speed of the locomotive at various values of draw-bar pull. The nominal rating of the standard eighteen ton locomotive is 7200 pounds draw-bar pull and by referring to the time curve "A" we find that the time curve crosses the horizontal line corresponding to sixty minutes at a point vertical -ly over a current value of 570 amperes. Then following up the vertical line corresponding to this current we find it crosses the draw-bar pull curve at a point on the horizontal line corresponding to 7000 pounds. The one hour rating of this locomotive is then found to be 7000 pounds draw-bar pull,and by similar methods it is seen that this locomotive will give 9000 pounds for forty minutes with the standard 75 degree Centigrade rise.

In selecting a locomotive therefore,it is necessary to select one that will give the requisite draw-bar pull but that will also remain within the limits of the 75 degree rise in temperature when operated continously.A motor may be large enough to slip the wheels and yet may be worked under long heavy grade conditions such that the continuous capacity may be exceeded. In this case a larger locomotive should be chosen for the given service.

The question of whether or not the a xles of a locomotive should be coupled in order to obtain the maximum draw-bar from the locomotive ,the power equipment of the locomotive being ample in each case to slip all the drivers,is a question which is

very interesting and one upon which several engineers have worked. Probably the reason that the Coodman Co. of Chicago, have investigated this question so thoroughly is that in their single motor type of locomotive they advocate its use because of the fact that they claim that by coupling the axles, that is by having their single motor armature geared to either axle, they gain the maximum draw-bar pull from the locomotive and further have uniform and symetry of drive.

Mr. L.B.Stillwell of New York says,"The limiting draw-bar pull which a pair of driving wheels can exert without slipping depends upon the weight carried by these wheels and the coefficient of friction between track and wheel rims." It follows that any reduction of weight carried by a pair of driving wheels proportionately reduces their maximum tractive effort. When a two axle truck is in service propelling a train, two forces external to the truck are in operation, namely, the pull at the draw-head (or at the holster) and the opposing pull of the wheel rims against the track. As the draw-head or holster is above the rail surface these two forces tend to tilt the truck, with the result that the load carried by the truck is unequally divided between the two pairs of wheels; the tendency being to decrease the weight carried by the front wheels and increase that carried by the rear wheels of the truck. The amount by which the weight on the rear wheels is increased and that upon the front wheels diminished is equal to the draw-bar pull multiplied by the height of the point of application of the pull above the rail and divided by the length of the wheel base of the truck. For illustration if the pull be 10,000 pounds the total weight on the truck 40,000 pounds, the height of the

point of application of the pull above the rail head 12" and the length of the wheel base 48", the tilting effect upon the truck will add 2,500 pounds to the weight effective upon the rear wheels and take the same amount from the weight effective upon the front wheels. Instead of each pair of wheels carrying 20,000 pounds, therefore under the conditions assumed, the rear wheels will carry 22,500 pounds and the front wheels 17,500 pounds. Or to assume another case, if the draw-head(or top of bolster in the case where tractive effort of truck is transmitted to load through bolster and king pin) be 12" above top of rail, the pull, 10,000 pounds, total weight on truck, 40,000 pounds and length of wheel base 24", the tilting effect upon the truck will add 5,000 pounds to the weight effective upon the rear wheels and take the same amount from the weight effective upon the front wheels with the result that, in this case, the rear wheels will carry 25,000 pounds and the front wheels 15,000 pounds.

In the case where the wheel base is 48" long, the adhesion of the front wheels of the truck is reduced 12½ per cent, and in the case where the wheel base is 24" long the adhesion of the front wheels is reduced 25%.

In addition to the tilting effect due to the couple formed by the pull at the draw-head and the opposing pull of the wheel rims against the track, the distribution of the weight upon the front and rear wheels of the truck is affected by the re-active forces operative between armature and fields of each of the two motors. The direction in which the weight is transfered by the transmitted force of reaction between armature and field and the quantitative value of such shifting depends upon torque of the

motors, gear ratios employed and the position of the motors with reference to the truck axles.

In cases where motors driving independent axles are connected electrically in series the slipping of one pair of wheels implies reduction of effective potential at the terminals of the motor driving the other pair of wheels. The result when one pair of wheels slips, therefore, is not usually slipping of the other pair of wheels, but a sudden decrease in torque of the motor which drives them and a consequent falling off of the total tractive effort.

In cases where the motors driving independent axles are connected electrically in parallel the slipping of one pair of wheels may or may not result in the slipping of the other pair, but in the majority of cases met with in practical operation both pairs will slip.

If the two pairs of wheels are connected by side rods, as in some locomotives, or by other equivalent mechanical connection, it is evident that the total weight upon the truck is at all times available for adhesion; any reduction in weight upon one pair of wheels being compensated by an equal addition to the weight upon the other pair of wheels.

To answer the question briefly, therefore, it is entirely natural and to be expected that for given weight and available motive power a locomotive with coupled drivers will exert greater tractive effort than one of similar dimensions and equipment in which the drivers are not mechanically coupled. Messers. L.Duncan and Lamar Lyndon agree with the theory of Mr. Stillwell. They say, " The limiting tractive effort of a locomotive, having independent

motors on its axles, is fixed by the slipping of that pair of wheels which has the smallest coefficient of friction". If a locomotive has two driving wheels each exerting a pull of three thousand pounds, the total pull is six thousand pounds. If the adhesion of the two pairs of drivers should change and the rear wheels have a greater weight imposed on them, while the weight on the front wheels is diminished, the motor on the front wheels, in attempting to perform one-half of the work, will slip them. The tractive effort exerted by these wheels is so greatly reduced by slipping that practically all the work is imposed on the rear wheels and as the draw-bar pull is much in excess of the adhesion of these wheels, they will also slip, and the locomotive loses its power until the movement of the wheels is stopped and a new grip on the track is obtained".

"Take an example of a 20 ton locomotive with a 48" wheel base, the draw-bar being 24" above the track, adhesion taken at 25%, we find that when the draw-bar pull is 10,000 pounds, the weight upon the rear wheels is sixty-six and two-thirds percent in excess of the weight upon the forward wheels. The change in weights may be computed by substituting in the formula

$w = Pxh/b$

$w = \frac{1}{2}$ of 20 tons 20,000 lbs.

$P = 10,000$ lbs.

$h = 24$ inches.

$b = 48$ inches.

$h/b = 24/48$ 1/2 , whence

$w = 1/2 \times 10,000$ 5,000

P = draw-bar Pull

w = weight oneach axle.

b = wheels base.

h = height of draw-bar above track.

Load on front axle = 20,000 - w 15,000 lbs.

Load on rear axle = 20,000 - w 25,000 lbs.

Decrease in tractive effort = 5000/20000 25% .

Excess of weight on rear axle over weight on forward axle = 25,000 - 15,000 10,000 lbs. The rear axle therefore, carries 10,000/15000, or 66.6% more weight than the forward axle.

Summing up, then, an electric mining locomotive having two axles which are driven by independent motors has the weight on the forward axle reduced by an amount proportional to the draw-bar pull; the pull it can exert is limited by the tractive effort of the least adhesive pair of wheels; and if one pair of drivers slips the other pair slips also.

If the two pairs of wheels be coupled or geared together it is clear in case slipping occurs that all the wheels slip together. Therefore the shifting of the weight due to the tilting effect of draw-bar pull, does not decrease the maximum draw-bar pull, for although one pair of wheels gives a less pull than the other pair, the sum of the two is always constant, and since they must act together the maximum draw-bar pull remains constant regardless of the tilting effect. The connecting of the wheels serves to automatically distribute the power of the driving motor between the two pairs of wheels in direct proportion to their respective adhesion to the rails.

In the case of two independent motor driven axles, if one wheel should come on to a greasy spot on the track where for even

an instant its tractive effort falls to nearly zero, the grip of the pair of wheels against the track is only about one-half of the normal grip, the pull the locomotive can exert also falls to half that which it possessed just before the wheel came on to the greasy spot. The result is, as explained above, that both pairs of wheels will slip unless the load on the draw-bar is one-half (or less) of the capacity of the locomotive.

If the two axles were geared together the four wheels would all act together and the wheel running over the slippery spot on the track would represent only one-fourth of the total tractive effort. Therefore the dimunition in the pulling power of the locomotive would be only 25% instead of 50%. In order to confirm these conclusions practically, a series of tests were made in the shops of the Goodman Mfg. Co. of Chicago. The apparatus used is indicated in Plate 44.

"A" is the platform of a scale on which the rail "B" (which represents one pair) was mounted. A similar section "C" was supported on sill "D". The draw-head "H" was coupled to a heavy fixed ring "R", through a dynamometer "G" on which readings of the draw-bar pull were taken. A steel plate "E" having its ends curved was placed between adjacent ends of the sections of rails "B" and "C". this served to take the horizontal pull of the drivers on the scale platform and at the same time, by the rocking motion through the very small distance of movement of the platform, formed a practically frictionless device.

These tests were made on a 12 ton mine locomotive having coupled drivers, the coupling being effected through a longitudinal shaft geared direct to each axle, the shaft being the armature

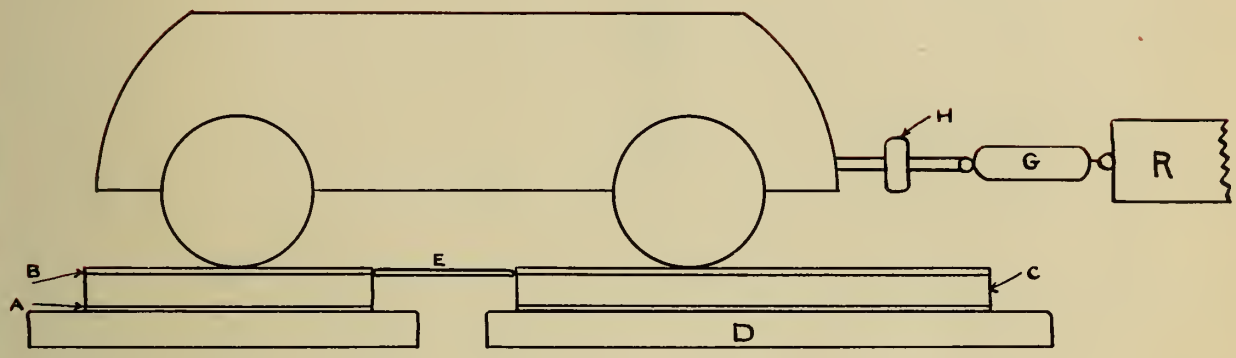


PLATE 44.

shaft of the single motor used.

Draw-bar height 15 and 5/8 inches, wheel base 48 inches, 33 inch wheels steel tired. The lay of the test is as follows:-

Slipping Tests.

Amperes	Draw-Bar Pull at slipping. lbs.	Draw-Bar Pull in % of weight. %
415	7000	29.15
412	7200	30.00
435	7750	32.30
Average	7316	30.48

Draw-bar height 9 and 5/8 inches, wheel base 48 inches, 33 inch wheels steel tired.

375	7000	29.15
410	7300	30.40
450	7500	31.30
418	7300	30.40
445	7700	32.15
445	7700	32.15
440	7500	31.30
405	7100	29.60
Average	7388	30.31

Tests were also made on the same locomotive having independently driven axles. Slipping took place at a draw-bar pull of about 5250 pounds with the 9.6 inch height of draw-head, and 4950 pounds with 15.6 inch height of draw-head, the tests being

as follows, respectively:-

Ht. of Draw-bar above rail. in.	Amperes	Draw-bar Pull at Slipping. lbs.	Draw-bar Pull in %wt. %
15.6	312	4950	20.6
9.6	334	5250	21.85

The average percentage of adhesion at point of slipping in the case of coupled drivers is about 45% in excess of that in the two motor equipment , same standard steel tires identical rails were used in each case.

To compute the maximum tractive effort which a locomotive having two independent axles may exert with a given coefficient of friction the formula is

$$P = A\,\phi\,/(2\phi - 1)\ ,\ \text{in which}$$

P = the maximum draw-bar pull.

A = the total weight of the locomotive.

ϕ = the coefficient of friction.

h = the height of draw-head.

b = the length of wheel base.

With coupled or geared wheels the maximum pull is simply ϕ A.

Taking as an example a 20 ton locomotive having independently driven axles, 48 inch wheel base, 24 inch height of draw-head and coefficient of friction 25% its maximum pull would be

$$P = 40{,}000 \times .25\ /(2 \times .25) \times 24/48 - 1$$

$$= 8{,}000 \text{ lbs.}$$

The same locomotive with coupled drivers would give a

draw-bar pull of, P = 40,000 x 0.25 10,000 lbs. or 25% more than the independently driven axle machine.

A series of tests were also carried on by the Goodman Co. on a 12 ton locomotive with coupled drivers using the same apparatus as shown in Plate 44 and with varying heights of draw-head. The results are given in the table below, and compared with the values observed are values computed by the above formula.

The two sets of quantities check within the limits of the errors of observation.

Wheel base 48 inches, 36 inch drivers.

Draw-Bar		Decrease in Load on Front Axle.		
Height in.	Pull lb.	Observed lb.	lb.	Computed lb.
12	6060	1520	160	1515
14	6100	1800	170	1780
16	6080	2000	210	2030
18	6010	2300	140	2280
20	6045	2700	180	2520
24	6030	3150	160	3015
35	6020	4500	190	4460

In conclusion these tests show that a locomotive has greater tractive effort under normal conditions with its drivers coupled together than if independently driven, which advantage becomes much greater in the case of slippery points on the rails or wheels. In practice a locomotive having coupled drivers will draw a greater number of cars than it would if the two axles were independently driven. Not only do the above mentioned engineers claim

that the connected axles are superior as regards draw-bar pull, but this fact was also observed by Mr. S.T.Dodd who in a paper entitled "Weight distribution on Electric Locomotives as Affected by Motor Suspension and Draw-Bar Pull", presented before the American Institute of Electrical Engineers, in July 1905, elaborated in considerable detail the theory and practice involved. Without specific quotation, his conclusions indicate definitely that with electric locomotives having independently driven axles there must be a radical revision of previously accepted conclusions as to the relation of draw-bar pull and weight on drivers.

Mr. Frank J. Sprague of New York says it may be safely stated without question, that in any case, and no matter what the construction of the locomotives, or the kind of arrangement of motors, mechanical coupling of drivers will result in hauling, with any given weight of locomotive, greater increased trailer loads, and more efficient and effective operation, all of which advantages will be most manifest under the adverse conditions attending the operation of electric equipment in mines.

Part IV.

Field and Factory Testing of Mine Locomotives.

Factory testing of locomotives is perhaps one of the most important stages in the production of a mine locomotive, yet most manufacturers of today test a locomotive only to see if it runs without heating the motor or bearings excessively. The Baldwin Westinghouse Co. is the only locomotive company which makes a really comprehensive test on their locomotive before shipping it to the mine. In testing their machine they set the completed locomotive upon a pair of adjustable rolls, said rolls being so arranged that they may accomodate any track gauge. Provision is also made for varying the wheel base by moving the rolls toward or away from each other. Suitable prony brakes are used to measure the power developed by the motors and a switch-board with the necessary electrical instruments enables a complete record to be made of the performance of every locomotive. The advantage of knowing that a locomotive will operate sucessfully under service conditions is most evident, and even though the utmost care is exercised in the design and construction of all parts, it is imperative that the proper action of the parts and their ability to operate continuously be insured by a running test. The electrical input of the machine being given by a voltmeter and an ammeter, the mechanical output being given by the prony brake and dynamometer tests, the efficiency of the locomotive may be computed by the formula

$$\text{Efficiency} \quad \frac{\text{Mechanical Output}}{\text{Electrical Output}}$$

These tests, the writer believes, are very conclusive and indeed a model which other companies should adopt.

In contrast to this testing plant, is the one of the Goodman Mfg. Co. of Chicago, Where one locomotive out of every hundred possibly, is tested for efficiency as in the Baldwin Westinghouse Co's. plant. The Goodman Mfg. Co. however test each locomotive to determine whether or not it will run, by operating it on a test track to see if the motor heats or the journal boxes get hot. This test is very good but yet it gives no idea of the efficiency and the draw-bar pull which the machine will develope, other than a comparative one, said data having been determined on the same type of locomotive when it was first manufactured.

Just as factory tests of locomotives are important to the manufacturer and the buyer of said locomotive, a comprehensive field test is of great importance to the mine manager or electrical engineer. The object of the field test is to determine exactly what the locomotive is doing in the mine, that is what draw-bar pull is developing and what efficiency is being obtained. A test of this sort should also indicate repairs necessary on the locomotive, condition of wheel rims, track and journal bearings.

To make the field test a volt meter, ammeter, and dynamometer are the necessary instruments. The volt meter and ammeter are wired in on the locomotive circuits and thus will give the electric input of the machine. Readings must be taken every thirty seconds in order that the readings may be averaged. The dynamometer is attached between the locomotive and the first car of the trip. On it is registered the pull which the locomotive is capable of exerting. When readings are taken on this instrument every thirty

seconds, and the average taken, a very accurate draw-bar pull will be obtained. The track over which the test is made should be as level as possible, and the speed of the locomotive should be uniform. Then knowing the distance traversed at a uniform speed and the average draw-bar pull, the work the locomotive is doing in foot-pounds per minute may be computed by the formula,

Work = Force x Distance.

Work = D.B.P. x Feet Traversed.

The work thus obtained in foot-pounds per minute is not all the work the locomotive is doing as it must be remembered that work is required to move the locomotive itself. Therefore if we determine from our previous calculations the draw-bar pull per ton of cars hauled, we may with a fair degree of accuracy add the draw-bar pull necessary to haul the locomotive (computed in the above way) to the draw-bar pull found above i.e.,

Total Draw-Bar Pull = Draw-Bar Pull of Trip +
Draw-Bar Pull of Locomotive.

The electrical input is given by the formula

$P = EI$, where P is the power in Watts
E is the Volts,
I is the Amperes.

The efficiency may thus be calculated from the formula,

$$\text{Efficiency} = \frac{\text{Mechanical Output}}{\text{Electrical Output}},$$

$$= \frac{\text{Total Draw-Bar Pull x Feet (Dis.)}}{\text{Watts}}$$

$$= \frac{\text{(D.B.P.)(Ft.Dis.)}_{\text{Trip}} + \text{(D.B.P.)(Ft.Dis)}_{\text{Locomotive}}}{I \times E}$$

If the track is not level and grades must be encountered

the draw-bar pull on the grade may be reduced to the horizontal draw-bar pull by multiplying the draw-bar pull on the grade by the cosine of the angle of the grade. This brings in an inaccuracy but the results will be surprisingly accurate.

It often happens that armatures are burned out, and furthermore it is sometimes very difficult to tell exactly where the armature is short circuited. The scheme which I propose requires only a switch board ammeter and about six to ten 16c.p. incandescent lamps. Regular 110 v. lighting circuit is used in making this test. The armature to be tested should be placed in an armature rack, so that it may easily be revolved. Then tie a strong string tightly around the commutator segments. Take the two leads from the power line, one of which has the lamp bank in series, lights being in parallel, and slip the two terminals under the cord on the commutator, the distance between the two leads being from 20 to 25 segments. Then touch adjacent commutator segments with the leads of the ammeter and a relative reading will be obtained. By testing one or two commutator segments one gets a normal reading of say 395 amperes (Relative reading only). By testing each two adjacent segments going in the same direction around the armature we should get 390-395 amperes reading on our ammeter for each segment. If however we have a short circuit the reading will fall to about 70, the reason being that a switch board ammeter without resistance is in reality a very delicate mili-voltmeter. The readings we obtain are then drops in voltage. We obtain a great drop in voltage through the armature coil, but the drop through a large copper segment is very small, hence the low reading for a short circuit. One point must be noted and that is that the number of

segments between the power leads must be the same when each section of the commutator is tested in order to get the same relative reading on the ammeter.

It is very well to test the drop in voltage, and this may be done by noting the pressure at the terminals of the generator, and noting the E.M.F. at various points of the trolley. If the drop in voltage is excessive, the feeder system should be installed, thus boosting the voltage at various points along the trolley line. Rail bonds are possibly the cause of more trouble as far as drop in voltage is concerned than any other part of the electrical equipment. It is important that the rail bonds therefore, be unbroken, that they be of good quality copper, that they be of low resistance, and that they be tightly connected between rail ends. The resistance of the bonds may be obtained by means of the Wheatstone bridge and a sensitive galvanometer,- the theory of the test being merely the theory of the Wheatstone bridge in which we get a relation between lengths of wire and standard voltage. By testing the bonds and thus obtaining the number of ohms resistance of each bond, a normal resistance could be obtained and other bonds required to come up to this standard.

Part V.

Electric Power vs Mules for Mine Haulage.

Electric haulage in mines is no doubt one of the most successful applications of electricity to mining. In one mine from which I have been enabled to get data, namely the #3 mine of the Peabody Coal Co. at Marion Ill., the advantage of electric power haulage over mule haulage is shown not only by reduced cost of haulage but by increased output, namely from 1400 tons to an average of 2000 tons per day, and as much as 2570 tons have been hauled in eight hours.

Before electric haulage was used in this mine 16 mules were used for gathering and 17 mules for main haulage work. Owing to the size of cars, grade and average haul of 1800 feet the output of the mine had reached its limit with mule haulage.

The problem of increasing the output was solved by installing two 15 ton Goodman locomotives with double end control. Trolley wire #0000 was used and fastened to the roof with trolley hangers, 8 inches outside of outer rail. The locomotives were of the two-motor type, 250 volts, rated at 8200 lbs. normal draw-bar pull. The locomotives have pulled it is claimed 17 loaded cars up a grade of 2½% and 1200 feet long. These cars weigh when empty 1050 lbs. and hold 6600 lbs. of coal so that the weight of the loaded trip would be over 72 tons.

The track gauge is 42 inches and the track measures 9000 feet over all, 40 lb. rails, bonded and cross-bonded being used, and laid on white oak ties. The curves on the locomotive haulage

track are from 40 to 60 foot radius, which gives 16feet to 18 feet from point of frog to point of switch on all cross-overs and turn-outs. The curves are elevated on the outer rail to suit a speed of 8 to 10 miles per hour, so that no speed will be lost in taking curves.

The power for operating the motors in the mine is supplied by a 175 KW generator belted to a 200 HP McEwen high speed engine 18 by 18 in., located in the power house of the mine. The generator also furnishes light for the underground haulage ways. From the switch board in the power house the current is transmitted over a 400,000cm. lead cable running down the manway and to the main haulageway of the mine.

The boiler plant consists of four 150 HP tubular boilers said boilers furnishing steam for hoisting engines and generator set. To make proper comparisons between mule and electric haulage the cost of two complete power units are given.

Cost of Electric Installation.

2	15 ton locomotives @ $2,300	$4,600.00
1	175 KW Generator and Switch board	2,400.00
1	200 HP McEwen engine 18 x 18 in.	2,000.00
	Foundations and placing Generator	300.00
2	150 HP Tubular Boilers 72 in.x 18 ft.	2,800.00
9000	feet Trolley wire	1,019.00
200	feet 400,000 cm lead cable @.55	110.00
665	Trolley hangers @ .65	432.25
768	Bonds @ .35	268.80

Cost of Electric Installation. (Con'd.)

75	Cross Bonds @ .35		26.25
18	Interchangeable trolley frogs @ 2.75		49.50
1	Extra 250 volt armature		375.00
2	Motor jacks @ 12.80		25.60
Extra fittings for motors			86.24
116½	Tons 40 lb. rail @ 28.25	3291.13	
Credit for 25 lb. rails		2056.75	
			1,234.38
6,055	White oak ties @ .10		605.50
65	Kegs 4½ x 4½ in. spikes @ 3.75		244.50
22	Split switches material and labor		374.00
Fish plates and bolts			280.00
Lumber for trolley supports			76.11
Sundries			54.55
Entire labor costs			3,810.21
	Total complete installation		$21,172.79

Daily Cost of Operating Electrically.

275 Working Days per Year.

Interest on Investment $21,172.79 @ 6%	4.62
Depreciation and repairs @ 8%	6.16
Taxes	.50
Fuel 5 tons @ .75	3.75
Oil and waste	.30
2 Locomotive runners @ 3.20	6.40
2 Trip riders @ 2.56	5.12

Daily Cost of Operating Electrically. (Con'd.)

1/3 Electrician	@ $75 per mo.	1.08
1/3 Fireman	@ 2.02	.67
Total daily operating cost electrically		$28.60
Cost per ton- 2000 tons per day		$ 0.014

Daily Cost of Mule Haulage.

275 Working days per year.

Average cost of mules $225.00 each.

Mule costs per day- one mule,

Depreciation @ 20 %	$0.163
Interest 6%	.049
Feed	.20
Shoeing and stableman	.158
Total	.57
17 Mules @ .57	$ 9.69
9 Drivers @ 2.56	24.24
Extra for team drives @ .15	1.20
Total	35.13
Cost per ton- 1400 tons	$ 0.025

Saving by Electric Haulage.

Mule Haulage, 1400 tons daily per ton	$ .025
Electric Haulage, 2000 tons daily per ton	.014
Difference	$ .011

This shows a difference of 1.1 cents per ton in favor of the electric haulage.

Thus one may say that besides increasing the output, and saving 1¢ per ton which means $20 per day, the installation pays for itself in four years. Besides the advantages of low cost of operation of the electric haulage system, are the simplicity of the entire installation, its flexibility, and the cost of maintenance, extensions, repairs, and changes in the transmission circuits, which are quickly and inexpensively made. The total expense of upkeep for the first year of operation of this system was under $ 100.00.

The Victor Fuel Co. of Denver, have investigated this comparative study of mules vs. electric haulage and have come to the following conclusion :- the mine operating as follows :- the output of the mine averages 1500 tons per day for 245 working days per year, amounting to 367,500 tons per year. The cars weigh 2400 pounds empty, and hold 3600 pounds making a total of 6000 pounds weight.

Comparative Figures for Mule and Electric Haulage.

Investment.

Mule Haulage.		Electric Haulage.	
14 mules @ 180	$ 2520.00	Engine, locomotive, boiler	
14 sets of harness	350.00	and generator	$ 9000.00
	$ 2870.00	Switches, insulators	
		and wire	1200.00
		Cost of erecting	1000.00
			11200.00

Mule Haulage.		Electric Haulage	
20 % depreciation	574.00	Interest 6% on $11200.	672.00
6 % interest on $2870	172.20	Depreciation on boiler engine, etc. 9%	810.00
		Repairs on boiler engine etc. 9%	810.00
		Depreciation on switches wire etc. 5%	110.00
		Repairs on switches wire etc. 5%	110.00
	$ 746.20		$ 2512.00

Operating Expenses- 245 days.

14 mules- feeding, shoeing repairing harness and care at 50¢ per mule per day	$ 1715.00	Engineer, power house at 75 per mo.	900.00
6 drivers @2.80	4116.00	Motorman @ 2.80	686.00
		Oil and waste	100.00
		Nipper on motor @ 1.50	367.50
		Sand	50.00
	$ 5831.00		$ 2103.50

Total Yearly Costs.

Interest and depreciation	$ 746.20	Interest and depreciation etc.	$ 2512.00
Working expenses	5831.00	Operating	2103.50
Total Costs	$ 6577.20	Total Costs	$ 4615.50

Cost per Ton Produced.

For 367,500 tons	0.0179	For 367,500 tons	0.0125

These costs agree fairly well with the costs just present-

ed, but I believe that an inaccuracy is present in the above set of costs, in that the tonnage is the same in electric haulage consideration as in mule haulage considerations. This is incorrect as any mine will have a larger output with motor haulage, and this should have been included in the above comparison.

The above costs just presented can not be said to be fixed costs, as the operating expense in electric haulage work varies greatly with local conditions. The following set of costs is an average set of actual costs and do not include the cost of installation. The haulage is charged on the pay roll with one-half of the electrician's services, one-fourth the engineer's, and one-third the fireman's, as their duties also include the care of other machinery than the generators, locomotives, and haulage system. The electric haulage operates only on day shift, while the air and other electric machines, such as electric pumps, coal cutters, etc., work both day and night, hence one-third the cost of fuel is charged to haulage account. The average length of haul is about 8000 feet and three 12 ton locomotives are employed. For the particular month taken, the output was 38,000 tons of coal.

Cost per Month.

1/2	Electrician's salary @ $90	$ 45.00
1/2	Day Engineer's " 70	35.00
1/3	Fireman's wages @ 150.	50.00
3	Motormen @ 50	150.00
3	Trip runners @ 45	135.00
Supplies (oil and repairs)		35.00
Depreciation and interest (12% per year)		250.00
	Total	$ 700.00

$$\frac{\text{Cost}}{\text{Tonnage}} = \text{cost per ton} = \frac{700}{38000} = 1.842 \text{ cents per ton}$$

Fuel cost per ton = 1.5 cents.

1/3 Fuel cost plus 1.842 cents = 2.342 cents per ton.

For gathering to the motor haulage way, twenty-eight mules and drivers are employed. The drivers are employed 20 days at $2.10 each, total $42 each, total for month $ 1176.

The cost per mule per day, covering depreciation, feed harness, and attendance is approximately 50¢ each, or 28 x 50 x 30 $420 per month; making a total cost of $ 1596 or 4.2 cents per ton for gathering, or a total cost from room to tripple of 6.54 cents per ton. The repairs on this plant, which has been in operation for five years, have been very few, and the cost will not be above 0.1 cent per ton of coal handled. In no case with a properly designed plant should this item exceed 0.2 cent per ton.

In conclusion the writer would say that electric locomotive haulage is preferable to mule haulage where the haul is over one-quarter of a mile. This is true because the saving in time made by the electric locomotive does not offset the enormous expense of installation for such a short haul. Over one-quarter of a mile haul however, the electric locomotive is the best form of haulage at the present time, the gasoline locomotive being a close competitor. In a good electric installation, the electric locomotive should make a saving of at least 0.9 cent per ton of coal over the cost of mule haulage, this estimate being a very conservative one.

Part VI.

Appendix A.

A Description of some Electric Haulage Installations in Illinois Mines.

The #6 mine of the Madison Coal Corporation is located at Divernon, Illinois, Sangamon County, Twp. 5N - R5W. The mine is one of the large mines owned and controlled by the Illinois Central Rail Road Co., the coal mined being used on the roads of the company.

The power plant of this mine consists of one Western Electric 100 KW, 250 volts, 400 amperes, 250 R.P.M., six pole generator; one General Electric Co. 220 volt, 688 amperes, 230 R.P.M., eight pole generator; and one General Electric Co. 250 volt, 400 amperes, 275 R.P.M., six pole generator. These generators are each separately driven by horizontal direct connected single acting steam engines. The three generators are wired in parallel, the number of amperes in the line being 1500, and the voltage 250 - 275.

The boiler plant consists of six horizontal tubular boilers rated at 150 horse power each. The boilers are manufactured by John Rohan & Sons of St. Louis, Mo. The operating steam pressure is from 100 to 122½ pounds.

The electric power line is carried down the shaft in lead covered cable, from whence it is distributed to operate two main haulage locomotives, outside wheel type, and single motor, manufactured by the Goodman Mfg. Co. of Chicago; fifteen undercutting machines, a thirty-five H.P. Deming Pump, and the lights in the main entry through out the mine.

The trolley wire used is 0000, figure 8 copper wire. The track gauge is 26 inches, a gauge entirely too small for safe operation of a locomotive at a high speed.

The trips hauled by the locomotive consist of 18 to 22 cars, each car carrying 3 tons of coal, weight of car being $1\frac{1}{2}$ ton, gross weight being $4\frac{1}{2}$ tons. The track is very level and therefore no trouble has been experienced on this account.

Several motor armatures have been burned out at this mine due to the fact that the small six ton locomotive used, has been overloaded, causing excessive heating of the armature coils. The cost of rewinding an armature being considerable, the advantage of having a locomotive of ample power and capacity is manifest. Plate 45 gives an idea of the general plan of the haulage ways over which the locomotive operates.

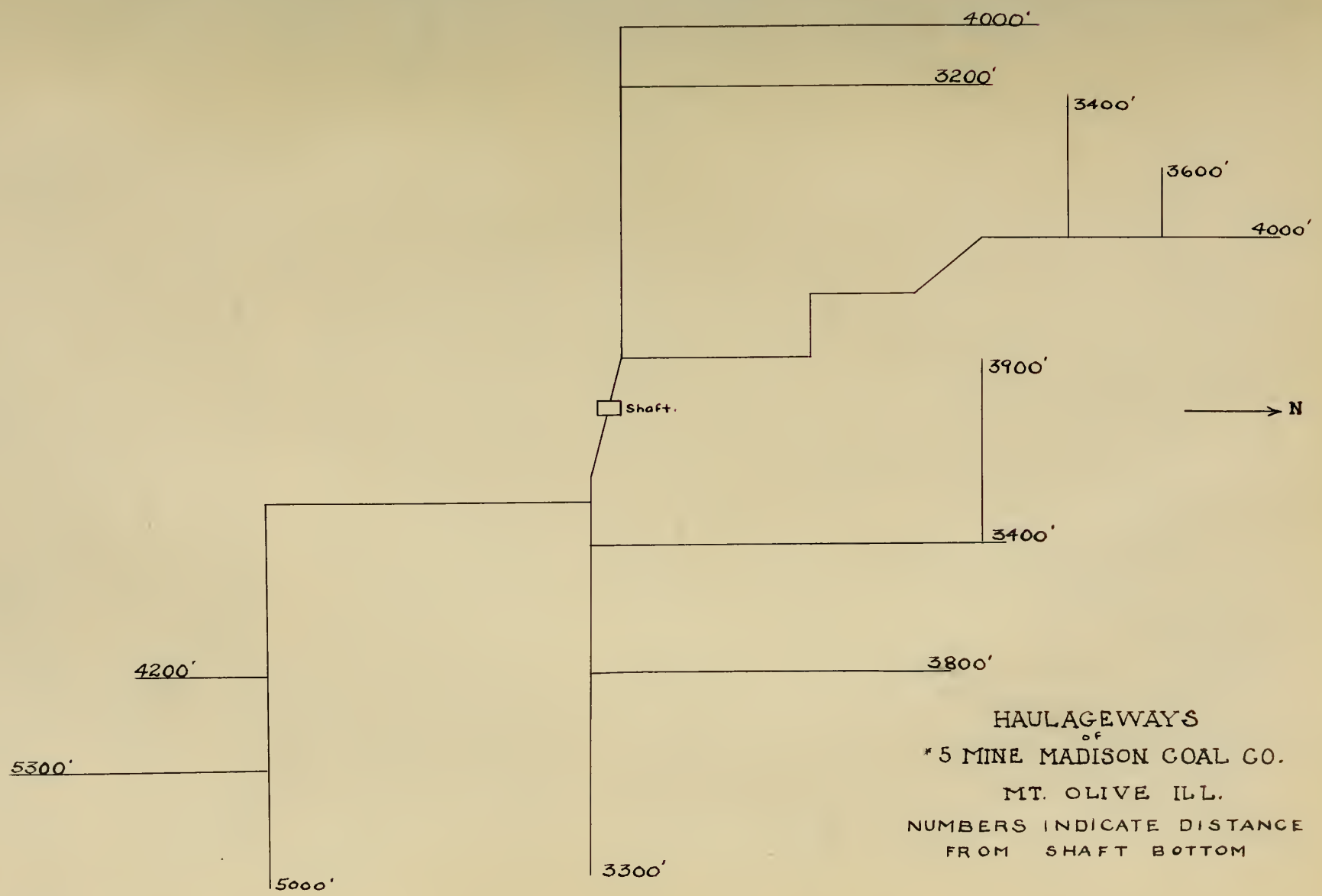
At the #5 mine of the Madison Coal Corporation at Mt. Olive Ill., two $7\frac{1}{2}$ ton, single type motor locomotive manufactured by the Goodman Mfg. Co. of Chicago are used for main haulage work, and mules are used for gathering. The power consists of one Goodman Generator, voltage 250 - 275, amperage 545, 150 KW, 225 R.P.M., eight pole machine coupled direct to a Brounell single acting horizontal engine 19"x 18". The boiler plant consists of one Heine boiler, 200 H.P., three Brounell boilers, 125 H.P. each, and two Rohan Boilers 125 H.P. each, making a total of 825 boiler horse power.

The cars have a capacity of 2800 to 3000 pounds of coal, and weigh 1250 to 1300 pounds, making a gross weight of about 4300 pounds. From 14 to 24 cars are hauled in each trip. The track gauge being only 26 inches as at the Divernon mine there is great

HAULAGEWAYS
of
#6 MINE MADISON COAL CO.
DIVERNON, ILL.

NUMBERS INDICATE DISTANCE
FROM SHAFT BOTTOM.

PLATE 45.



HAULAGEWAYS
of
*5 MINE MADISON COAL CO.
MT. OLIVE ILL.
NUMBERS INDICATE DISTANCE
FROM SHAFT BOTTOM

PLATE 46.

danger of derailment, and furthermore the 7½ ton single motor locomotives are not large enough to carry the loads imposed upon them. The engineering staff of the Madison Coal Corporation is planning on the installation of tandem locomotives, their claim being that this will avoid enlarging their track gauge, and yet have all the advantages of the 12 or 15 ton locomotive. I maintain that this is by far the most expensive procedure. I should reccomend the installation of a new track having 40 pound rails and a 36 inch gauge, at a possible cost of $1500, credit of $2000 being allowed on old rails. The present single motor locomotive should be used for making up trips and gathering. Two 12 or 15 ton locomotives should then be purchased and the output of the mine would not only be increased, but the repairs and the cost of haulage would be greatly reduced. Plate 46 shows the general plan of the haulage ways of this mine

The #2 mine of the Superior Coal Co. near Sawyerville, Ill., has perhaps one of the best electric installations in the State of Illinois. The mine is owned by the Northwestern Rail Road Co. and the output of the said mine is used by the company. The mine has an output of 4200 tons per day, with a record of 4583 tons and 1900 pounds.

The power plant consists of a Westinghouse Electric Co. generator 200 KW, 275 volts, 730 amperes, 200 R.P.M., six pole machine, direct connected to an Ideal Engine, manufactured by the A.L.Ide & Sons of Springfield, Illinois.

The haulage system consists of one Jeffrey 12 ton, two-motor locomotive, one Jeffrey 15 ton, two-motor locomotive, three single motor Goodman locomotives and twenty-seven mules. The Jef-

frey locomotives are used in the main haulage roads; the three Goodman locomotives are used for relaying between the partings and the main entries, and the mules are used for gathering. This relay system is indeed one of the best systems in motor haulage. The main entries are laid out 4000 feet east and 4000 feet west of the shaft. The main haulage locomotives operate to a point 3000 feet from the shaft bottom. At this point the relay Goodman machines carry the empty locomotives up 1000 feet into the rooms, where mules are used for gathering. The advantage of this system is that by the time the main haulage locomotives arrive at the relay point, the Goodman machine arrives with a trip of loaded cars. The large locomotives then return to the shaft bottom with the loaded cars, and the Goodman machine carries the empty cars up into the rooms, from whence the mules carry the cars to the face. Plate 47 illustrates the haulage ways of this mine.

HAULAGEWAYS
OF
#2 MINE SUPERIOR COAL CO.
SAWYERVILLE, ILL.

NUMBERS INDICATE DISTANCE
FROM SHAFT BOTTOM.

PLATE 47.

Appendix B.

Later Information on the History of Electric Mine Locomotives

In 1889, the Thomson-Houston Electric Co., installed in the Erie colliery of the hillside Coal & Iron Co., the locomotive illustrated in Plate 48. This locomotive was of the single motor type and the transmission was a set of gears instead of chain and sprocket as in the preceeding machines. It is said that this machine is still in service.

A locomotive known as the "Terrapin Back", was built by the same company in 1891 and several of these machines have operated continuously since this time. Plate 49 is an illustration of this type of machine.

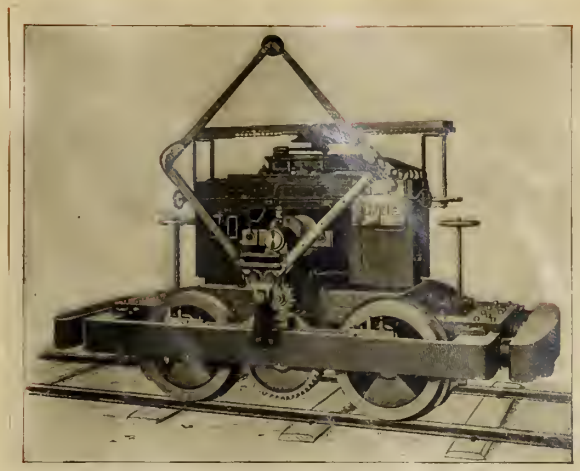


Fig. 1.—H. M. 80. Mine Locomotive. Installed in 1889. Still in Use.

Plate 48

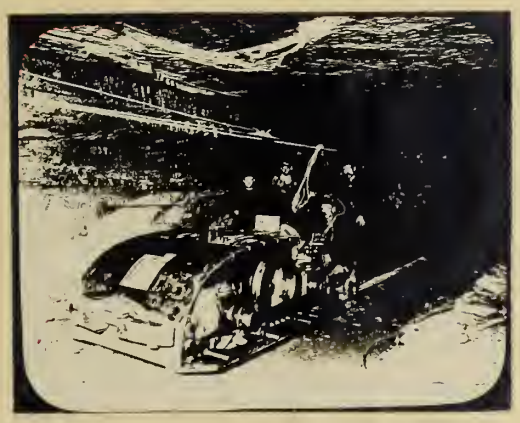


Plate 49

UNIVERSITY OF ILLINOIS-URBANA
3 0112 086829360